

# Climate Information and Water Management in the Carolinas

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Carolinas  
Integrated  
Sciences &  
Assessment

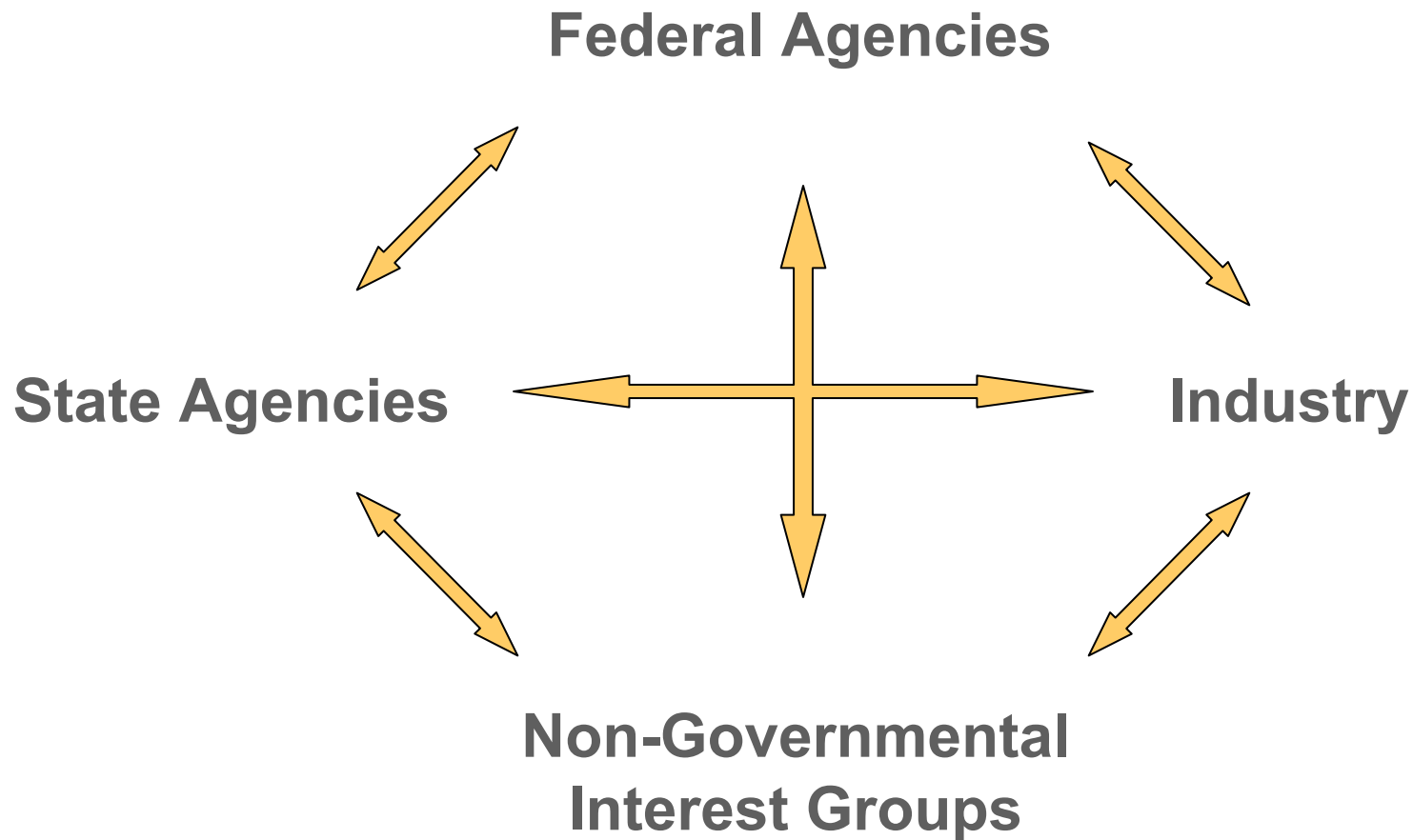
# Primary CISA Goal

Improve the range, quality, relevance,  
and accessibility of climate information  
for management of water resources in  
North and South Carolina.



Carolinas  
Integrated  
Sciences &  
Assessment

# Stakeholders in the Water Resources Arena



# Working with Stakeholders in the Carolinas

- Extensive early consultation
- Recognize major ongoing discussions among water resources interests
- Engage in, and advance that dialogue as it relates to climate
- Collaborate in conducting timely, relevant research to meet community needs
- Select the most salient issues
  - Strategic long-term water management concerns
  - Major public and private risks

# Sample Meetings and Interviews

- SC Department of Health and Environmental Control
- NC Dept of Environment and Natural Resources
- NC Water Resources Research Institute
- US Geological Survey
- SC Pulp and Paper Association
- Hydropower Licensees: Duke Power, SC Electric & Gas (dam operators)
- Federal Energy Regulatory Commission (FERC)  
stakeholder meetings with diverse state/federal agencies and citizens groups represented (Homeowners Association, Trout Unlimited, Palmetto Paddlers, Riverkeepers, Coastal Carolina, US Fish and Wildlife, National Parks)

# Building Tools with Stakeholders

- Drought forecasts for community water system managers
- Fire risk index for the SC Forestry Commission
- Evaluating ENSO impacts in the Carolinas
- Hydroclimatology decision support

# **Drought Forecasts for Community Water Systems Managers**

- Water systems that serve at least 15 connections or 25 people on a year-round basis (US EPA)
- Over 700 systems in South Carolina
- Drought is a major concern
- Translating long-lead forecasts to drought forecasts
  - At a local scale
  - Related to the state regulatory guidelines

# 1998-2002 Drought

## Impacts on Water Resources

- 1000+ Dry Wells – no financial assistance available
- 30 Water Systems with mandatory restrictions
- 100 water systems with voluntary restrictions
- Reduced water availability for fire protection



# South Carolina Drought Response Act

- 1985: Established procedures for monitoring, managing, and conserving water resources during periods of drought
- Drought Response Committee
  - monitors drought stages with specific indices
  - coordinates state response
  - recommends or mandates action (e.g. water restrictions)



# South Carolina Drought Response Committee

- **Statewide Committee Members**

SC Dept. of Natural Resources  
SC Emergency Management Division  
SC Dept. of Health and Environmental Control  
SC Department of Agriculture  
SC Forestry Commission

- **Local Committee Members**

Agriculture  
Counties  
Commissions of Public Works  
Power Generation Facilities  
Regional Councils of Government  
Soil & Water Conservation Districts

Industry  
Municipalities  
Domestic users  
Private water suppliers  
Public service districts  
Special Purpose Districts

- **Invited Participants**

Farm Service  
United States Dept. of Agriculture  
Clemson Agricultural and Natural Resource Program

National Weather Service  
US Geological Survey

# South Carolina Drought Stages

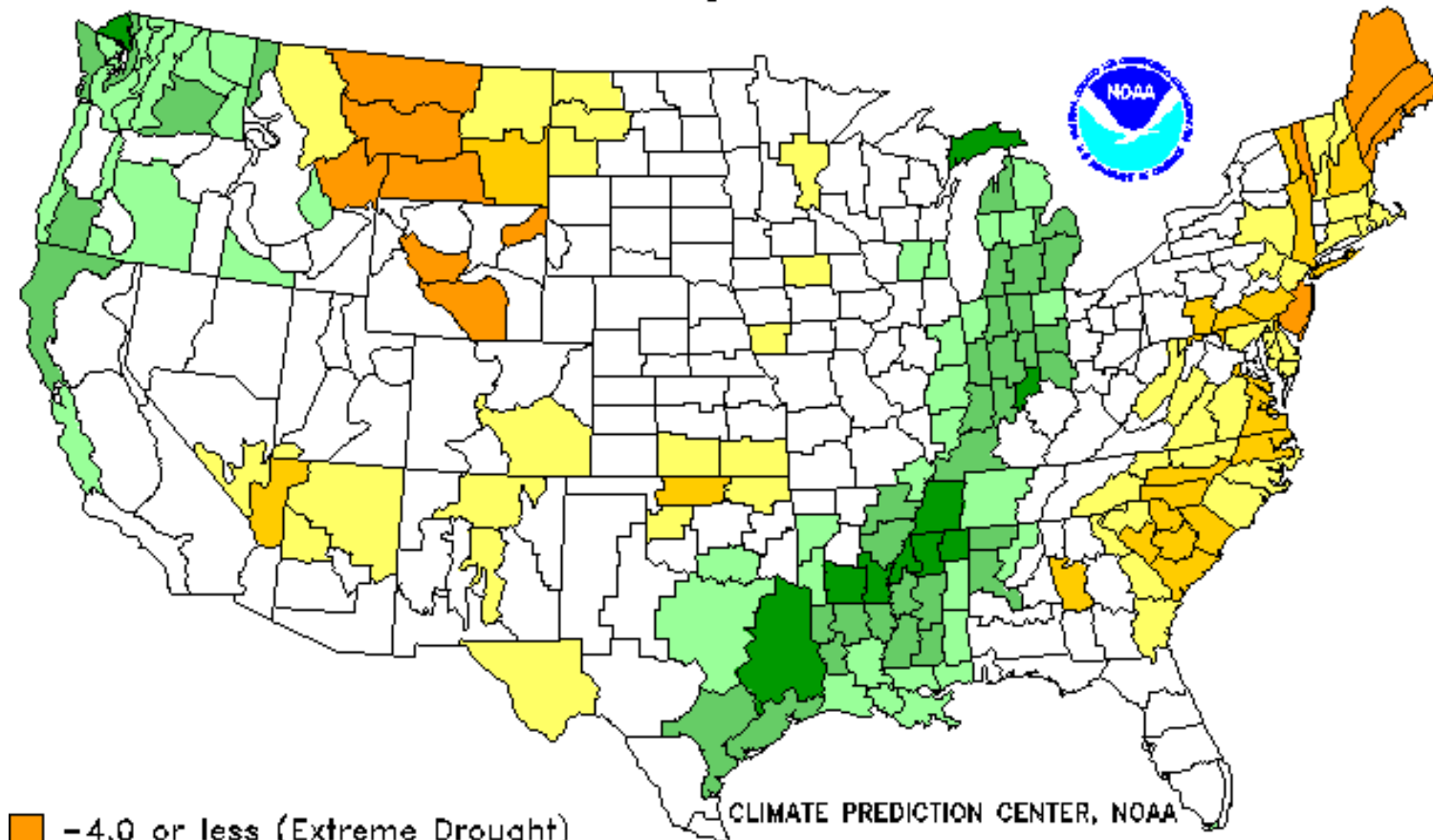
Drought Stage (SC Drought Response Committee)	Palmer Drought Severity Index (PDSI)	Standardized Precipitation Index (SPI)	Keetch-Byram Index
1 Incipient	-0.50 to -1.49	0 to -0.99	300 to 399
2 Moderate	-1.50 to -2.99	-1.00 to -1.49	400-499
3 Severe	-3.00 to -3.99	-1.50 to -1.99	500-699
4 Extreme	$\leq -4.00$	$\leq -2.00$	$\geq 700$

# Value of Anticipating Drought Stages

Drought Severity Index by Division

Weekly Value for Period Ending 5 JAN 2002

Long Term Palmer



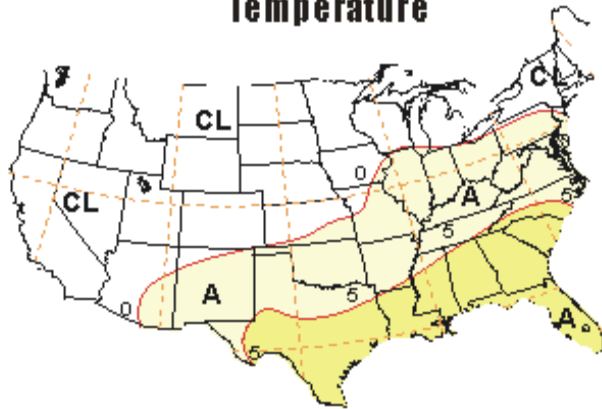
- -4.0 or less (Extreme Drought)
- -3.0 to -3.9 (Severe Drought)
- -2.0 to -2.9 (Moderate Drought)
- -1.9 to +1.9 (Near Normal)

- +2.0 to +2.9 (Unusual Moist Spell)
- +3.0 to +3.9 (Very Moist Spell)
- +4.0 and above (Extremely Moist)

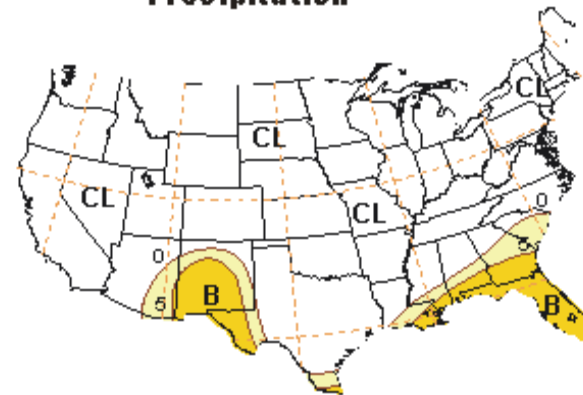
# January 2002 CPC Forecasts

## Monthly Outlook

**February 2002  
Temperature**

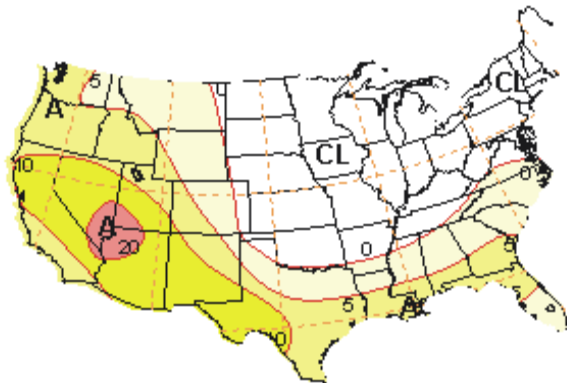


**February 2002  
Precipitation**

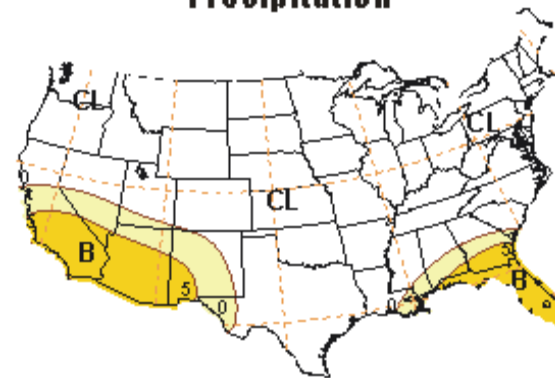


## Seasonal Outlook

**February - April 2002  
Temperature**



**February - April 2002  
Precipitation**



Release Date: January 17, 2002

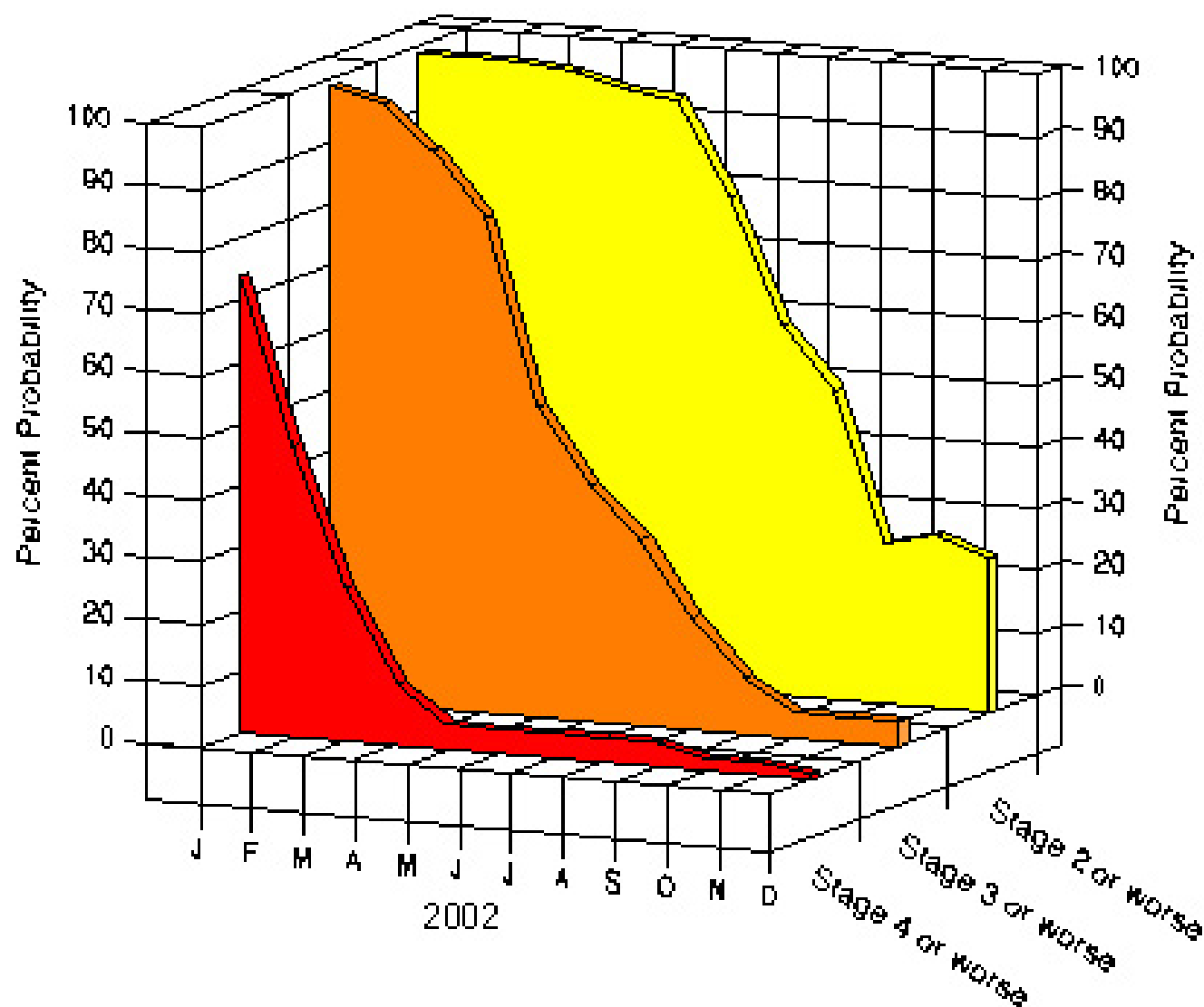
# Estimating Future Drought Probabilities

- Resample from climatology
- Incorporate long-lead forecasts

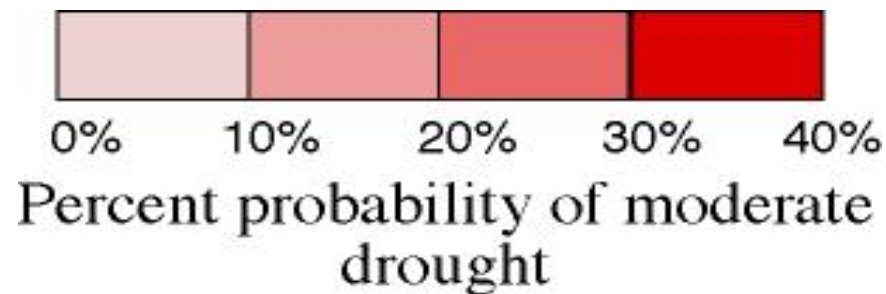
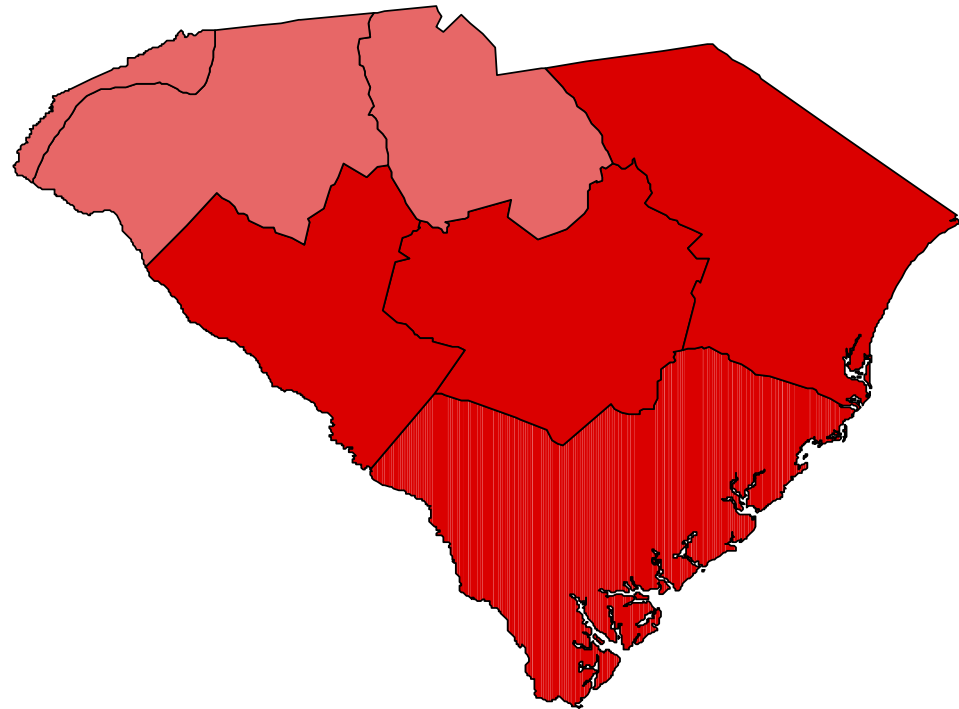
Precipitation	<b>Below</b> 1934,1943,1960,1965, 1975,1980,1993,1998	<b>Normal</b> 1944,1951,1952, 1964,1979,1983, 2003	<b>Above</b> 1946,1948,1963,1973, 1976,1977,1990,1997	<b>Above</b>
	1940,1942,1958,1962, 1971,1984,1996,2001	1950,1954,1959, 1970,1972,1978, 1992,1994,2002	1935,1936,1938,1945, 1953,1961,1968,1974, 1997,2000	<b>Normal</b>
	1931,1932,1933,1937, 1941,1947,1969,1987, 1999	1939,1949,1956, 1957,1966,1981, 1986,1988	1955,1967,1982,1985, 1989,1995	<b>Below</b>
<b>Temperature</b>				

# Exploring Ways to Present Forecasts

Predicted drought stages using 24-month standardized precipitation index

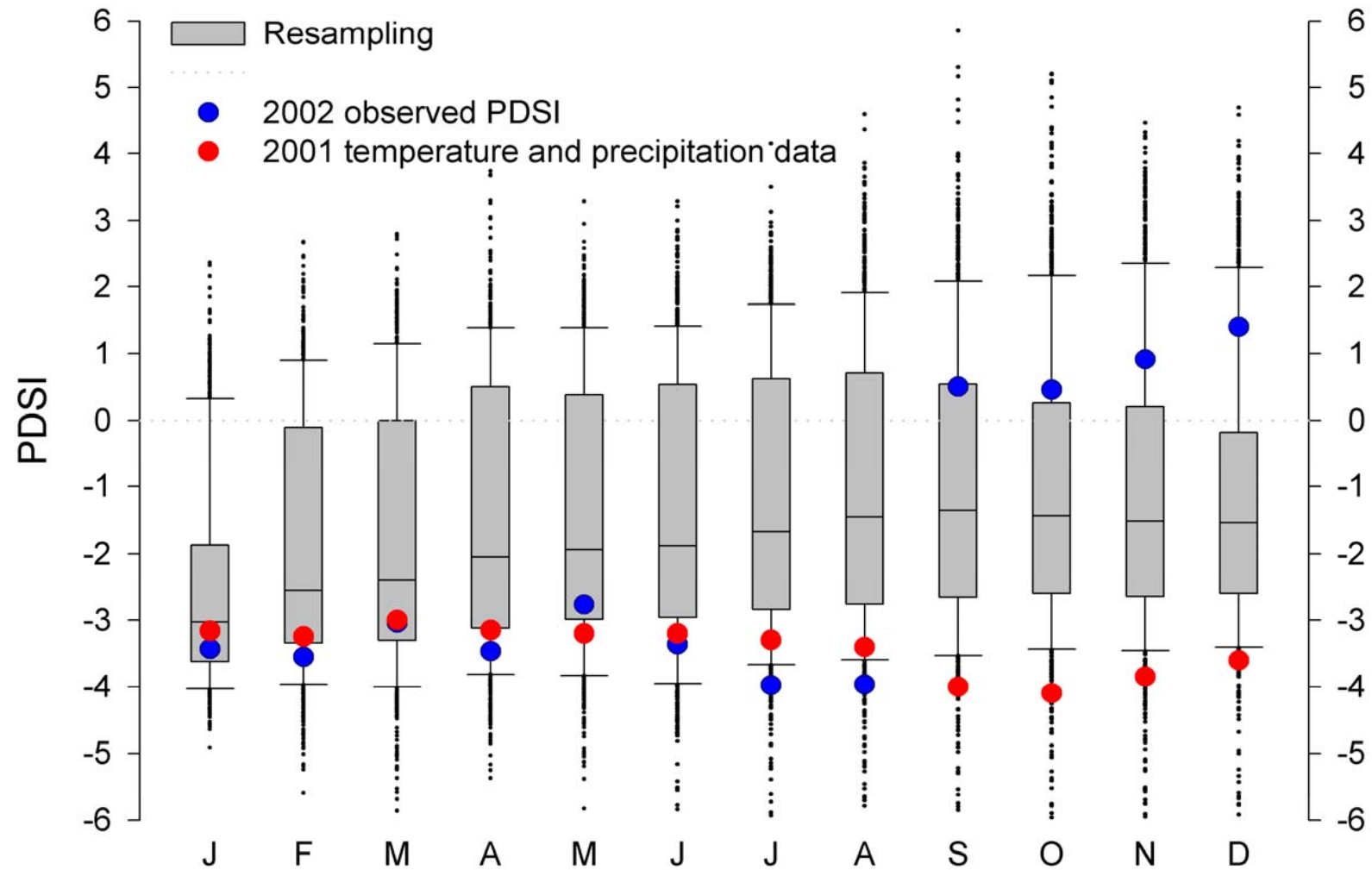


# May 2002 drought prediction (made on January 1, 2002)





# Palmer Drought Severity Index Central South Carolina 2002 Scenarios



# Fire Risk Index for the SC Forestry Commission



# Drought Impacts on SC Forestry



- Southern Pine Beetle - worst on record in SC

## Losses:

2002 \$220 million                      2001 \$75.8 million

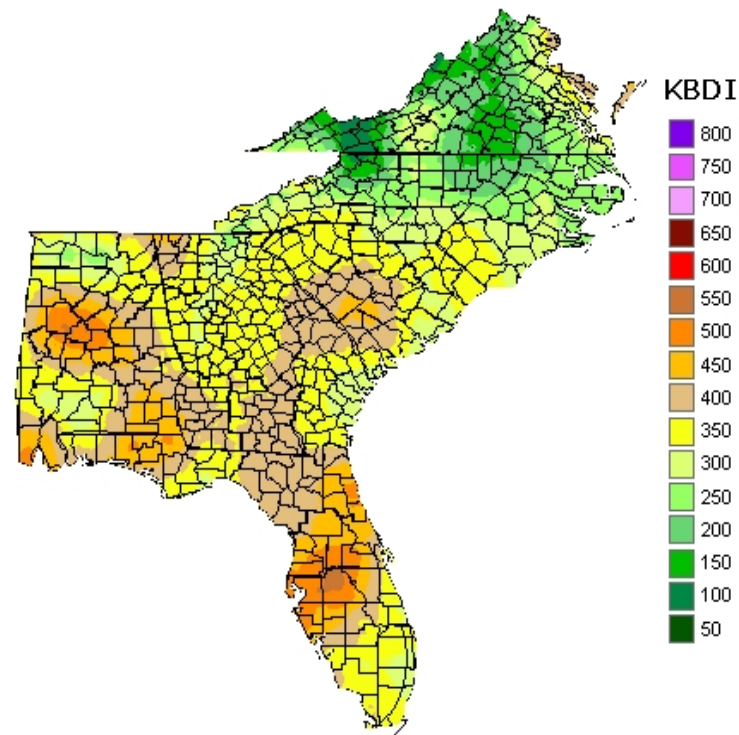
2000 \$40.7 million                      1999 \$9.5 million

- 50% annual forest growth - \$276 million per year
- Increase in forest fires and acres burned
- Salt water encroachment threatened thousands of pines along coastal streams



# Keetch-Byram Drought Index Mapping

Supplement existing tools



# Keetch-Byram Drought Index Map North and South Carolina

Maps

Graphs and Tables

Choose variable and date:

KBDI

Draw

06/03/2005

06/05/2005

06/04/2005

06/03/2005

06/02/2005

06/01/2005

05/31/2005

05/30/2005

## Layers

☒ Data

- 0.00 - 200.00
- 200.00 - 400.00
- 400.00 - 600.00
- 600.00 - 800.00

☒ Counties☐ Climate Divisions

- CDs in NC
- CDs in SC

☐ Drought Management Area

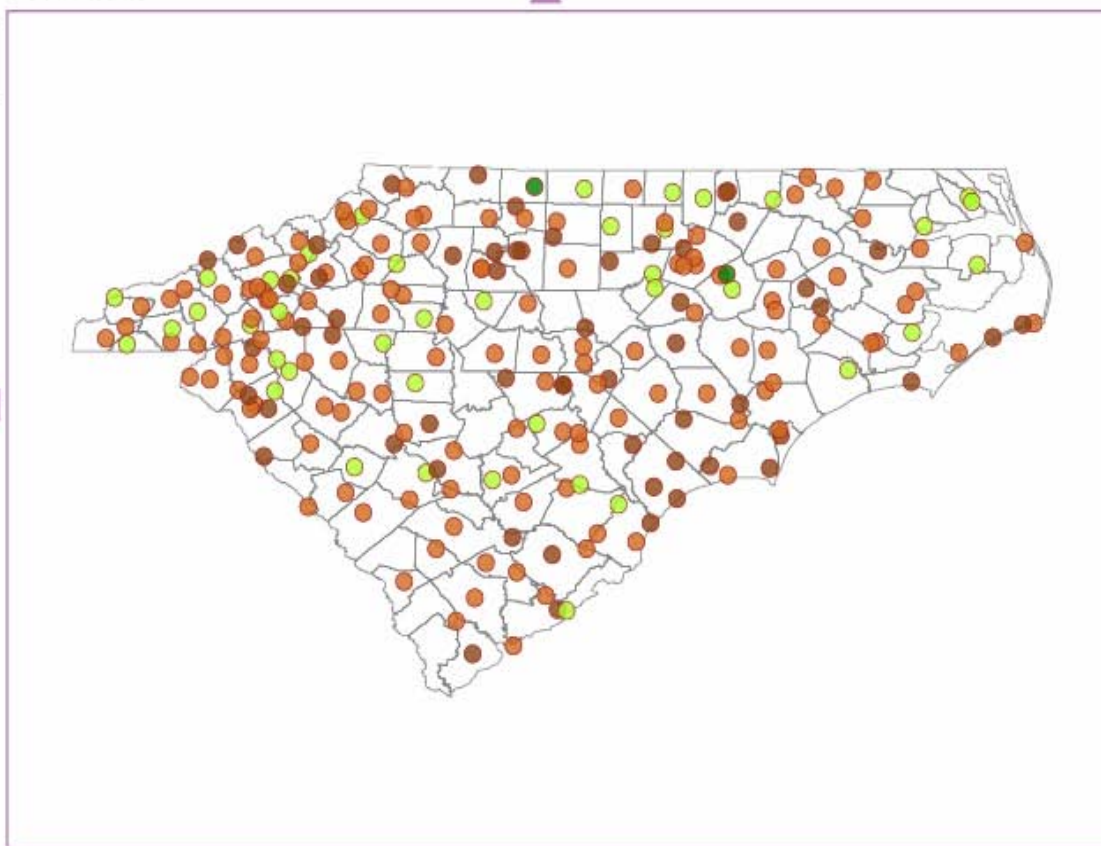
- Central (Santee)
- Northeast (PeeDee)
- West (Savannah)
- Southern (ACE)

☐ Hydrology

- River
- Lake



X: -81.55 Y: 34.33



## Information

### Stations

UCAN ID: 17364  
Station Name: LORIS 1 S  
Keetch-Byram Drought Index: 76  
24-Hour Precipitation: 0.01  
Daily Maximum Temperature: 89

### Counties

State: SC  
County: Barnwell

Author: Jinyoung Rhee (rheej@sc.edu)  
Last update: 13 April 2005





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Maps

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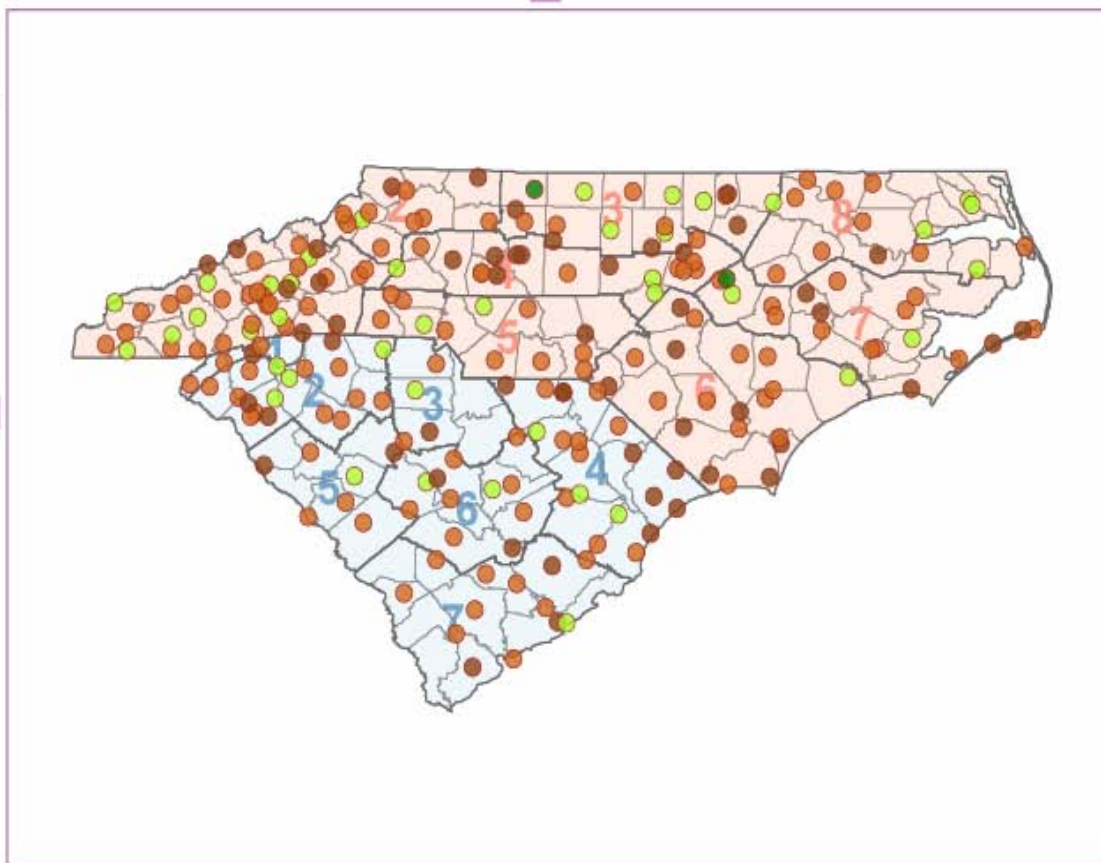
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Author: Jinyoung Rhee (rhee@sc.edu)  
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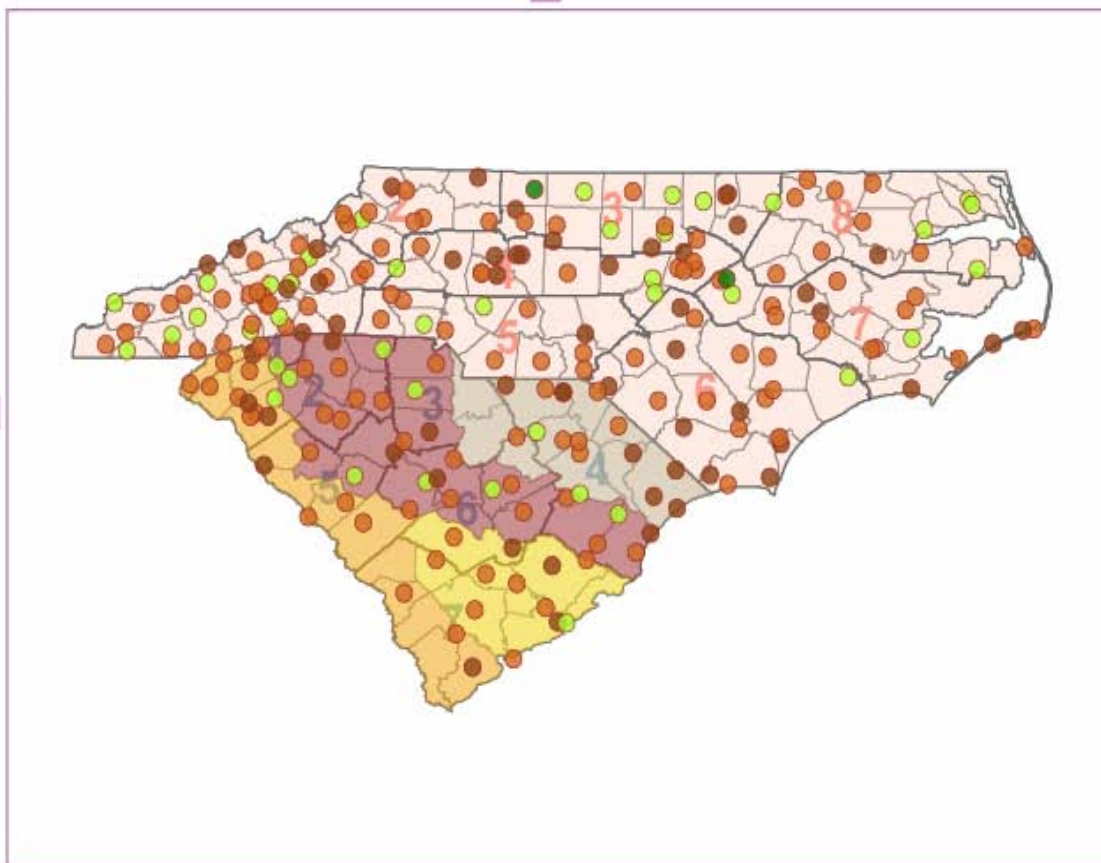
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Graphs and Tables

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06/03/2005

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X: -81.55 Y: 34.33



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- 200.00 - 400.00
- 400.00 - 600.00
- 600.00 - 800.00

☒ Counties☐ Climate Divisions

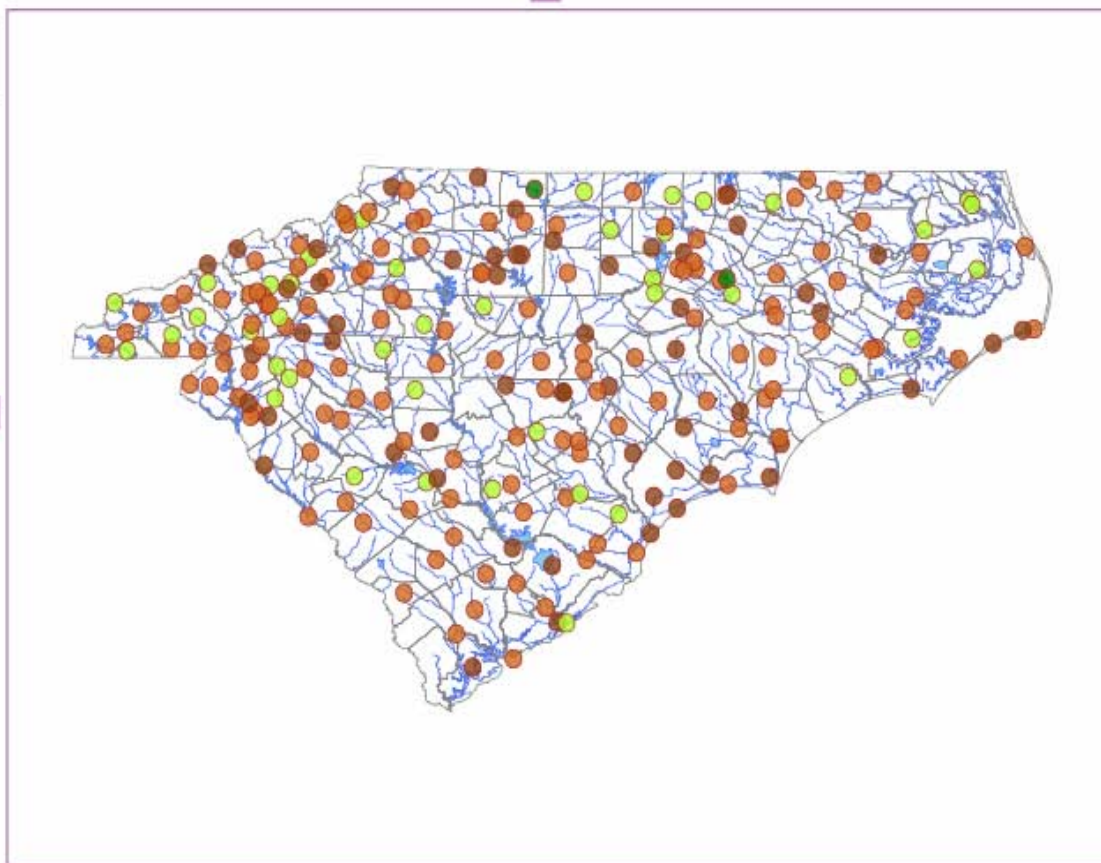
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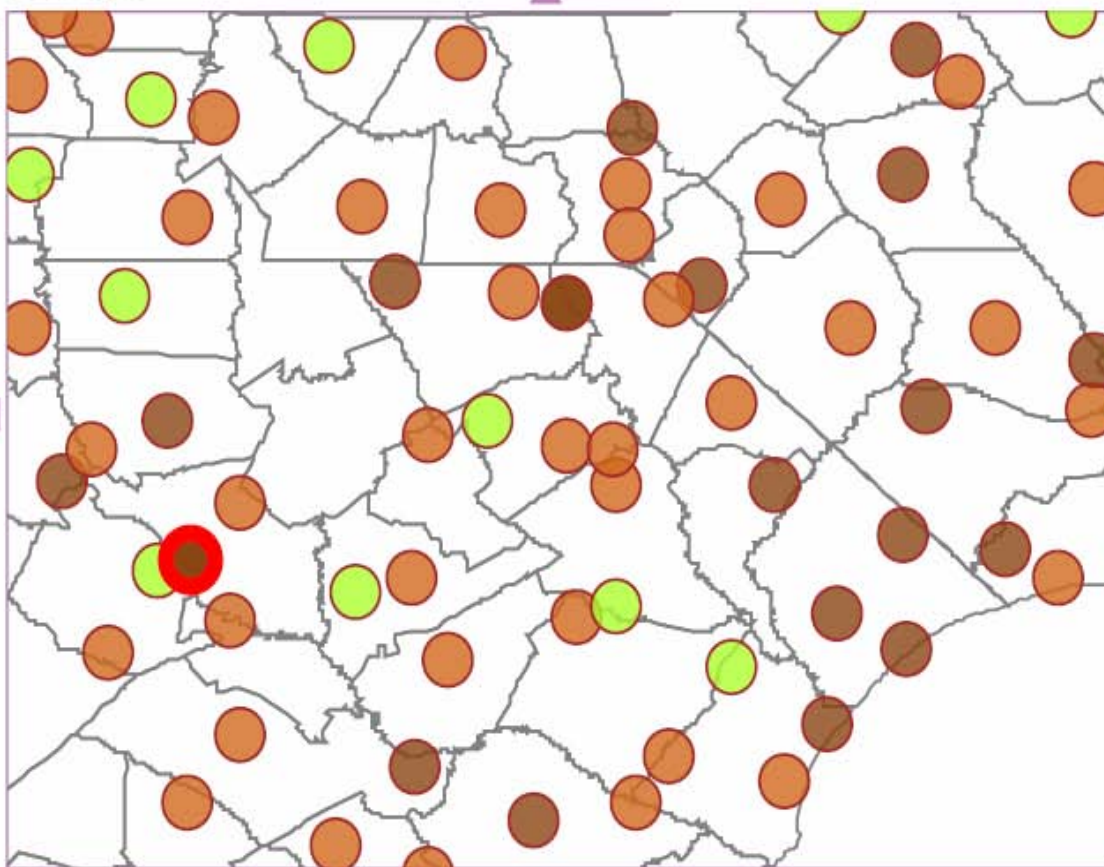
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- Northeast (PeeDee)
- West (Savannah)
- Southern (ACE)

☐ Hydrology

- River
- Lake



X: -80.96 Y: 34.01



## Information

### Stations

UCAN ID: 17298  
Station Name: COLUMBIA UNIV OF SC  
Keetch-Byram Drought Index: 103  
24-Hour Precipitation: 0.62  
Daily Maximum Temperature: 92

### Counties

State: SC  
County: Richland

Author: Jinyoung Rhee (rheej@sc.edu)  
Last update: 13 April 2005

# Keetch-Byram Drought Index Map North and South Carolina

Maps

Graphs and Tables

Choose variable and date:

KBDI

06/03/2005

Draw



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- 200.00 - 400.00
- 400.00 - 600.00
- 600.00 - 800.00

☒ Counties☐ Climate Divisions

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☐ Drought Management Area

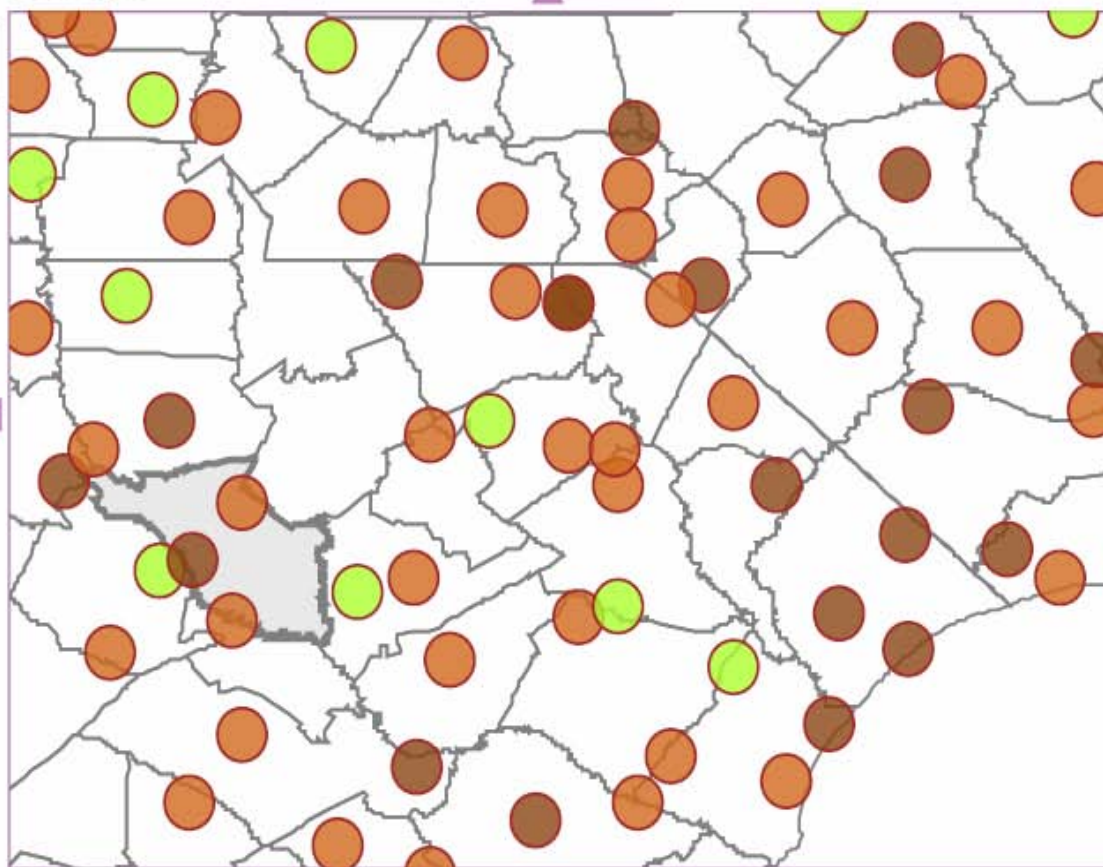
- Central (Santee)
- Northeast (PeeDee)
- West (Savannah)
- Southern (ACE)

☐ Hydrology

- River
- Lake



X: -80.79 Y: 33.99



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## Keetch-Byram Drought Index Map North and South Carolina

Maps

Graphs and Tables

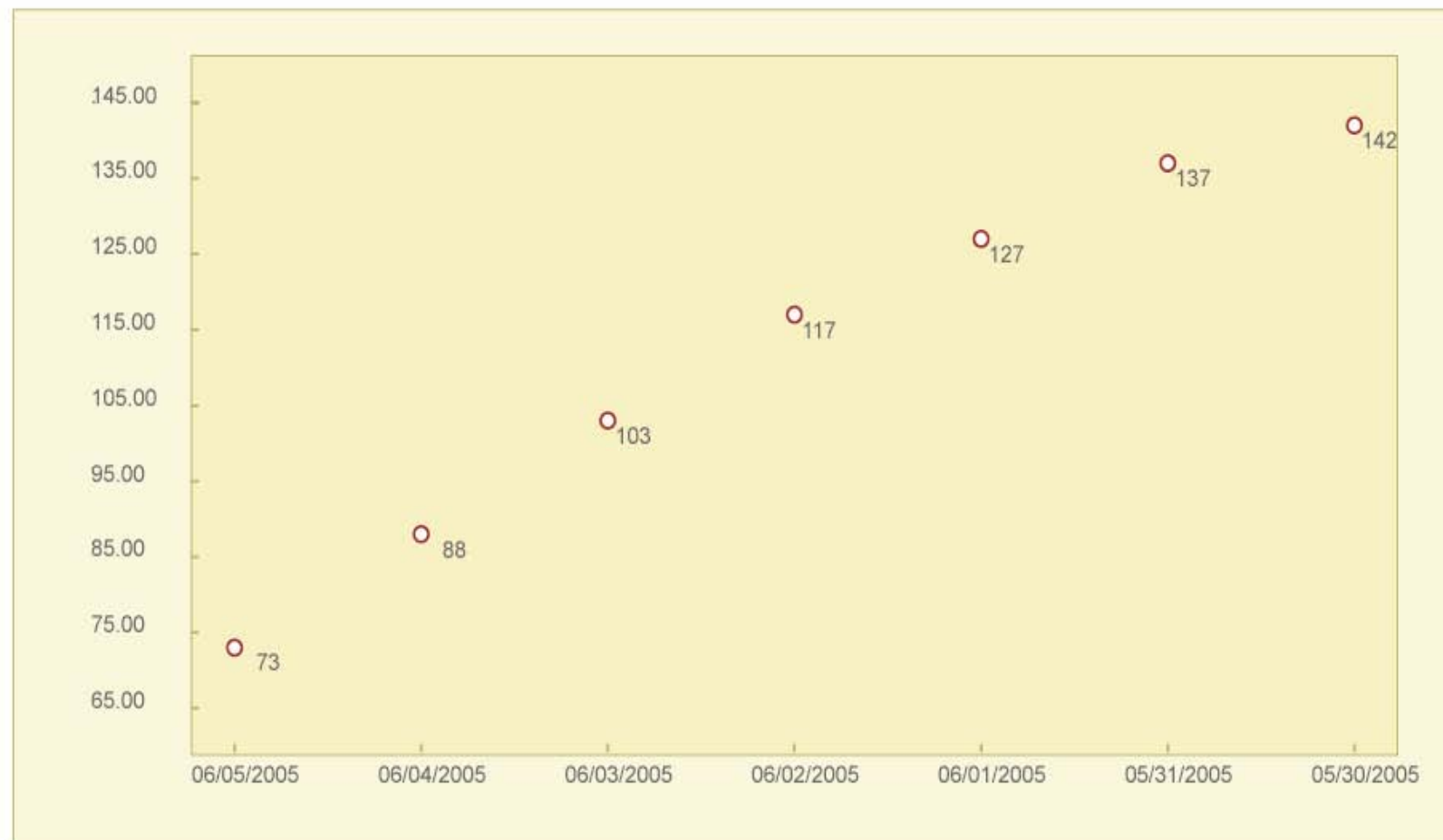
Choose variable and date:

KBDI

17298

Draw Graph

Create Table



# Working with Stakeholders during the Development Process

“My comments at first glance - something to start with:

- Point source KBDI better than nothing, but doesn't give a good picture of KBDI across the state.
- Interpolation between the points is needed to show a better [statewide map](#) with different colors shaded according to the KBDI. 100s of KBDI is okay for color differentiation. Should be able to create a state map with entire map colored with KBDI ranges. Same for 24 hr precip.
- Additional Variables - Precip for 2 day, 3 day, 4 day, 5 day...,
- Precip duration (by hour), [Lightning Strikes](#) or Activity if measurable at the Coop Weather Stations.
- [Hourly wind direction and speed](#). Hourly RH.
- How does this KBDI calculation correlate with that of FTS (Forest Technology Systems) Fire Wx Plus and WIMS.
- Graphs and tables - need better labeling. Maybe [another graph style](#). Tables not working yet. What is being graphed?
- [More contrast in colors](#) needed.
- Another possibility: KBDI based on [Doppler rainfall estimates](#) as being done in TX and FL.”

# Further Comments

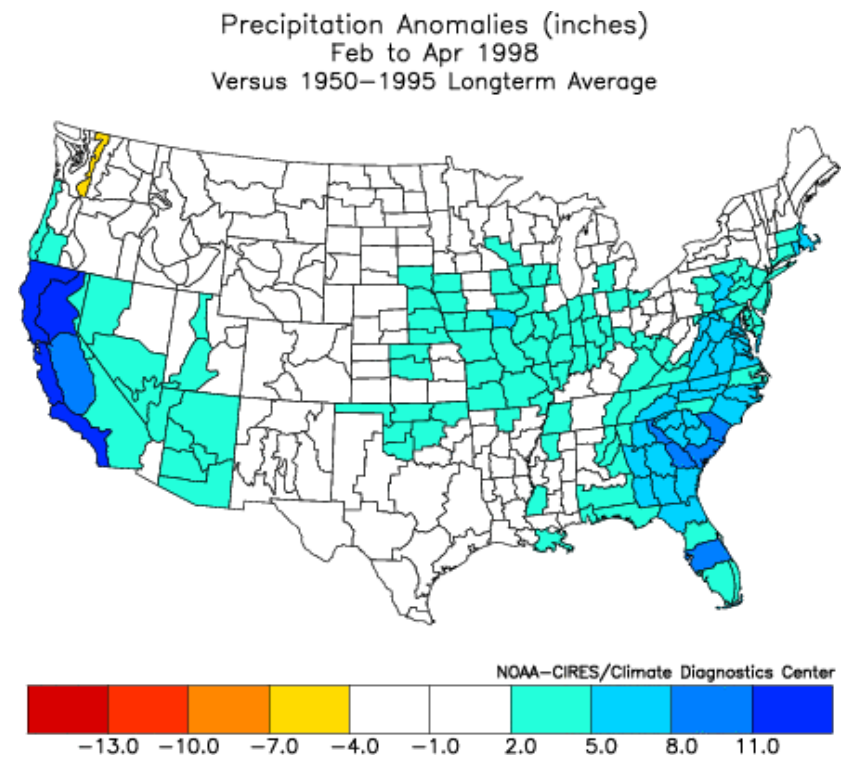
“My comments in response to Larry and taking a look at the application:

- I am impressed with the application and feel it would be a benefit to the SCFC effort to provide Fire Wx forecasts
- The output could then be presented as a choropleth map (different colors) for both KBDI and 24 hr. precip.
- Past a daily outlook, such as weekly, bi-weekly, monthly, etc. could also be produced
- Doppler estimates are probably beyond the scope of this project, but should definitely be considered if it expands
- I didn't see a table view, but I like the graph, it could use some improvements in style though



# Evaluating ENSO Impacts in the Carolinas

- Stakeholders' perceptions of ENSO impacts
- Discerning and communicating variability of ENSO expression



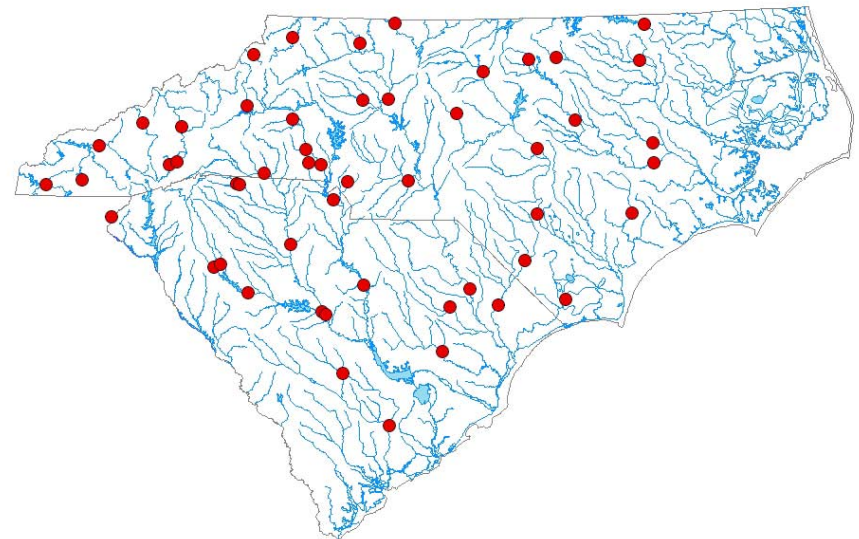
# ENSO Signal in the Carolinas

- Water supply: long term streamflow records
- Water quality: simulation modeling
  - Catawba River watershed – NC/SC
  - Streamflow and water quality
  - Land use interactions

# Long-term streamflow

- Data

- USGS daily discharge
- Aggregated to monthly volume
- Analysis by nominal season
- 53 gage sites, 55-105 years



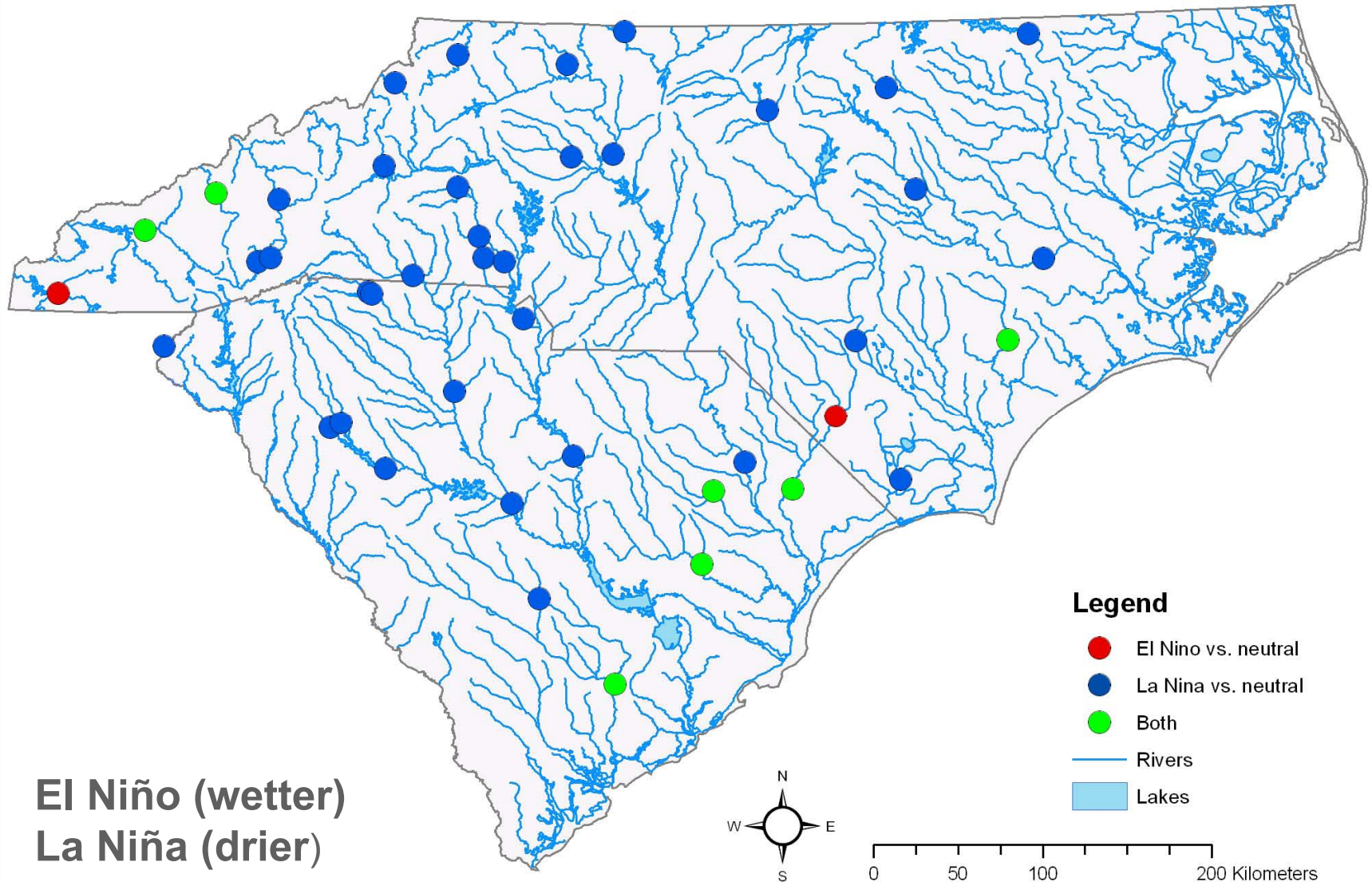
- Methods

- SAS PROC GENMOD
  - Least square means
- Differences in discharge
  - La Niña, Neutral, El Niño
  - $p \leq .05$

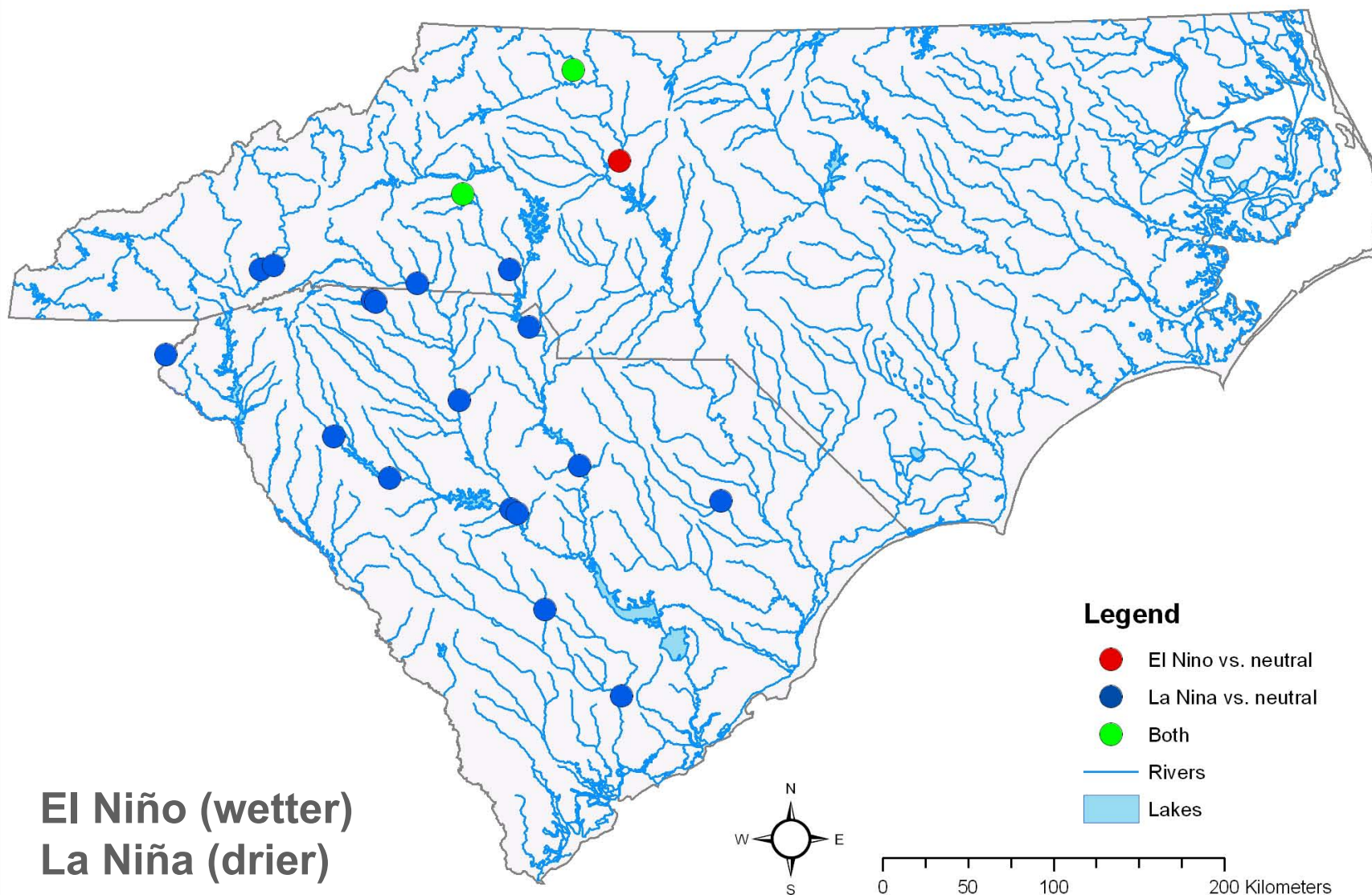
- Winter – Jan, Feb, Mar
- Spring – Apr, May, Jun
- Summer – Jul, Aug, Sep
- Autumn – Oct, Nov, Dec



**Winter:** Gage sites with significant difference in streamflow based on the ENSO cycle

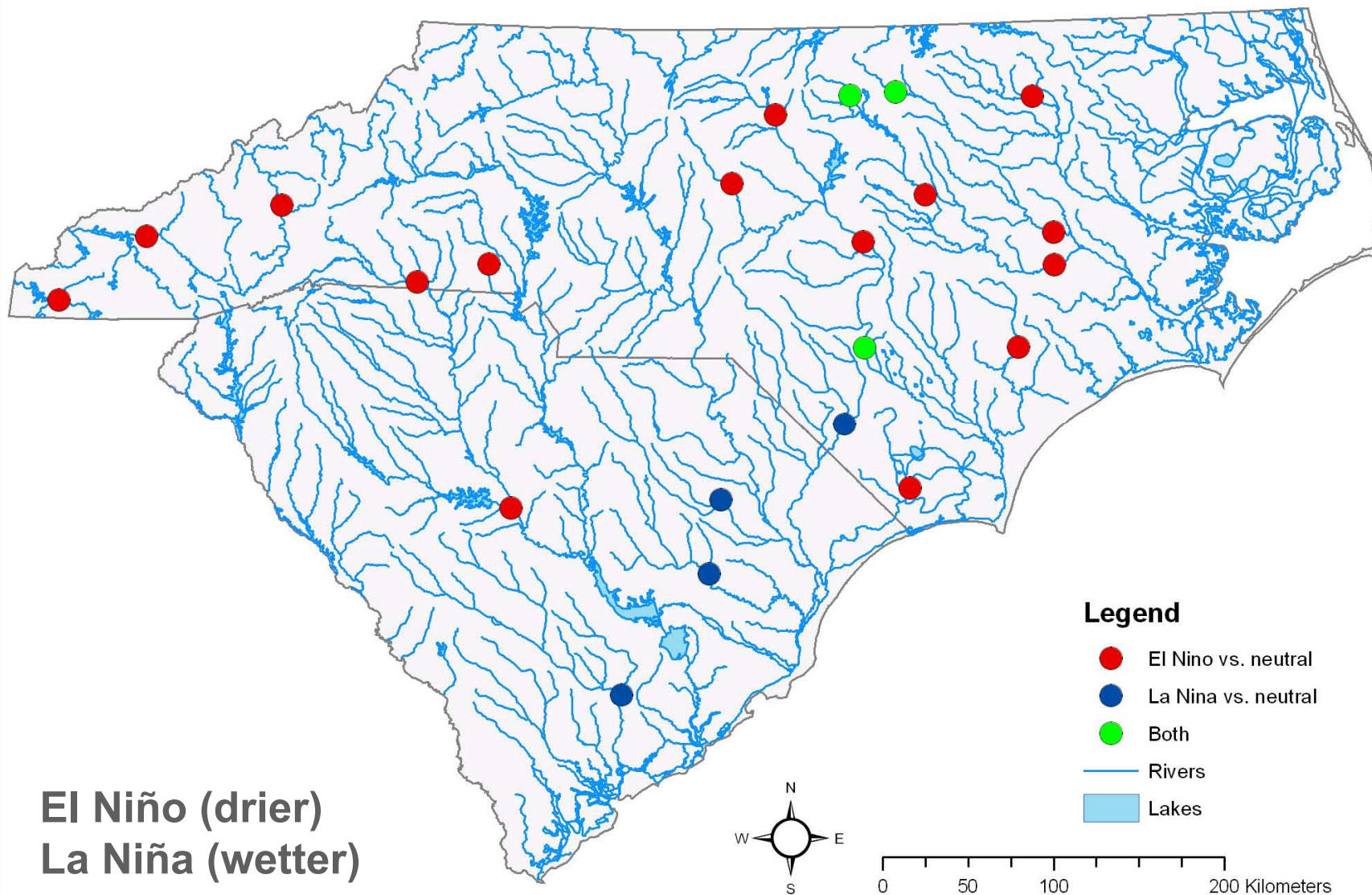


**Spring:** Gage sites with significant difference in streamflow based on the ENSO cycle



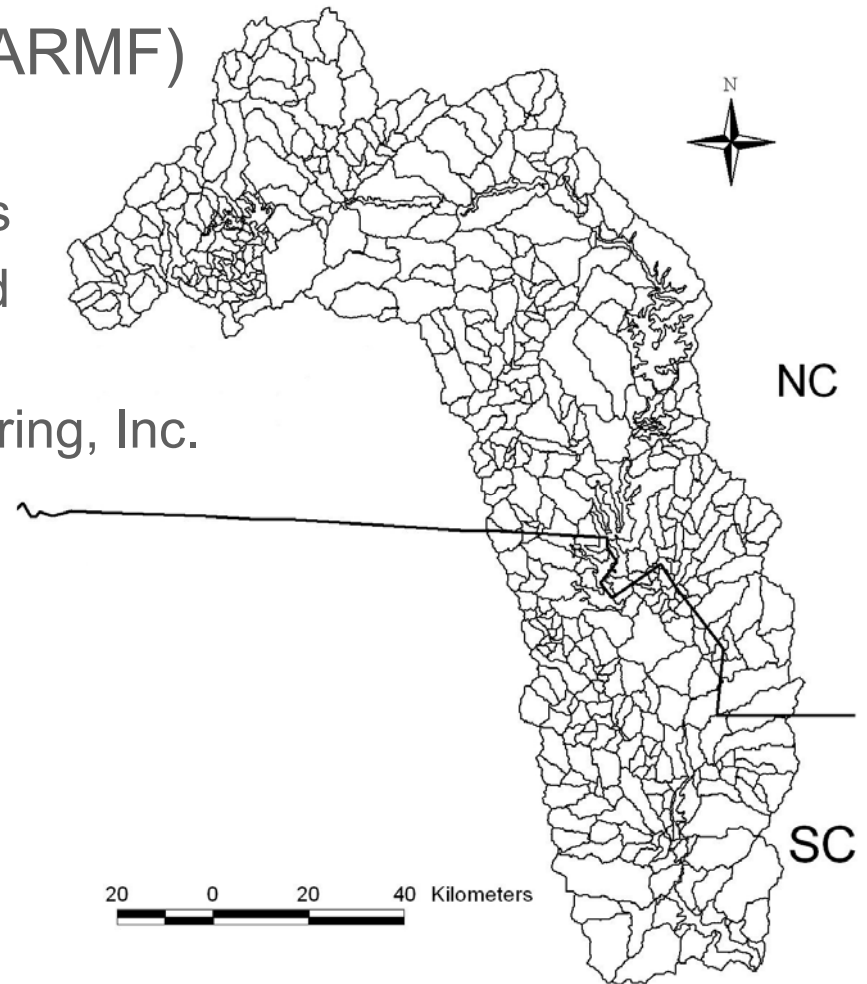


**Summer:** Gage sites with significant difference in streamflow based on the ENSO cycle

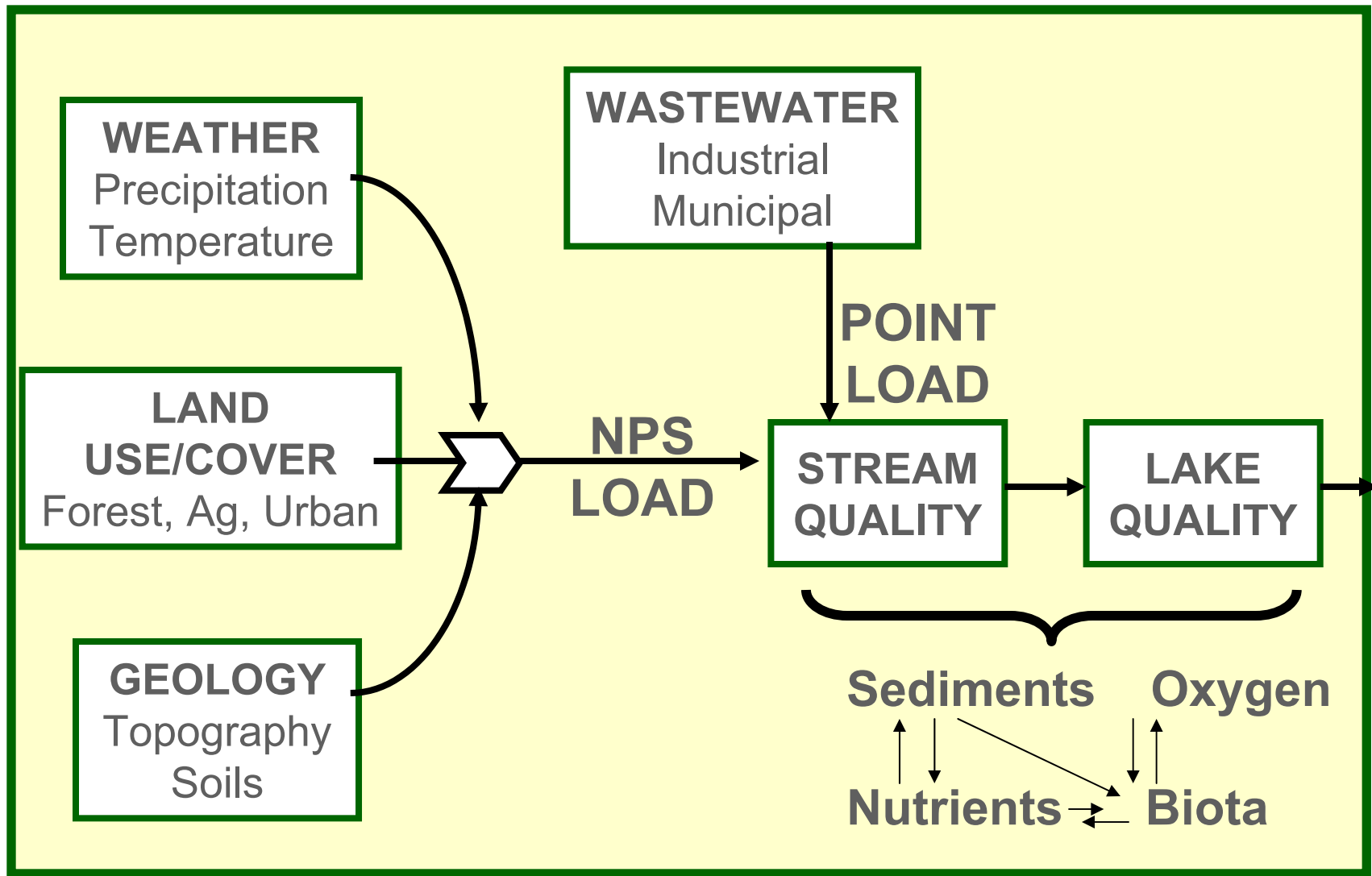


# ENSO Signal and Water Quality

- Watershed Analysis Risk Management Framework (WARMF)
  - Mechanistic simulation model
  - Based on public domain models for water quality, hydrology, and watershed processes
  - Developed by Systech Engineering, Inc.
- Watershed divided into 649 catchments
  - Individually parameterized
- 29 met stations

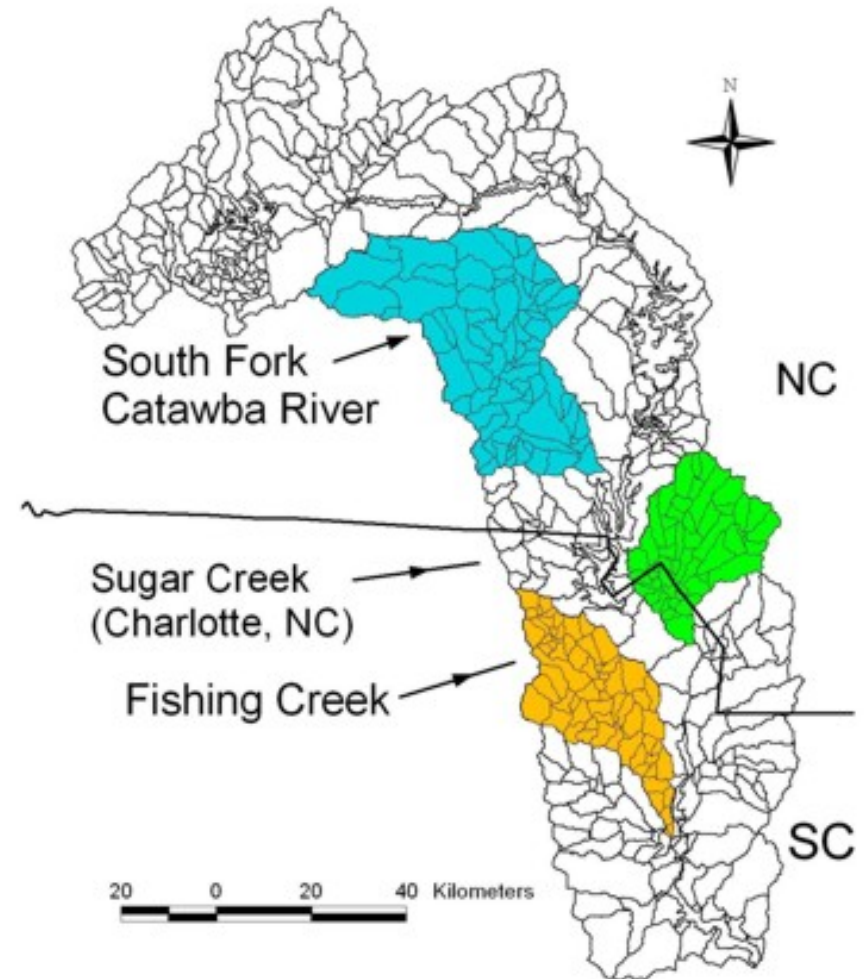


# WARMF Model



# WARMF Simulations on Catawba-Wateree

- Simulation interval
  - Jan 1992 – Dec 2001
- Extracted results at three spatial scales
  - Headwater – 88
  - Intermediate – 10
  - Outlets – 3
- Parameters evaluated
  - Precipitation, streamflow, runoff ratio, total nitrogen, total phosphorus
- SAS PROC GENMOD
  - ENSO phase
  - Land use interaction
  - ENSO phase classification



# Discharge and Nutrients

## Compare El Niño to La Niña

		Headwaters	Intermediate	Outlets
Discharge	Winter	>	>	>
	Spring	>	>	>
	Summer	>	>	>
	Autumn	>	>	>
Total N	Winter	>	>	>
	Spring	<	<	>
	Summer	<	<	<
	Autumn	<	<	<
Total P	Winter	>	>	>
	Spring	>	>	>
	Summer	<	>	>
	Autumn	<	>	>
		$p \leq .05$	$p \leq .10$	



# Moving Towards A Decision Support Tool

http://129.252.3.45 - Climate Impact on Water Resources :: - Microsoft Internet Explorer

File Edit View Favorites Tools Help

## Climate Impact on Water Resources

Catawba River Basin: WARMF Simulation

| Simulation | Results |

### Request Simulation

Beginning date (9/1/1997~)  Ending date (~9/30/2003)

Time steps per day  Climate Scenarios

Simulations (Hydrology +)

- ☒ Water quality
- ☐ Sediment
- ☐ Fertilizer
- ☐ Point source

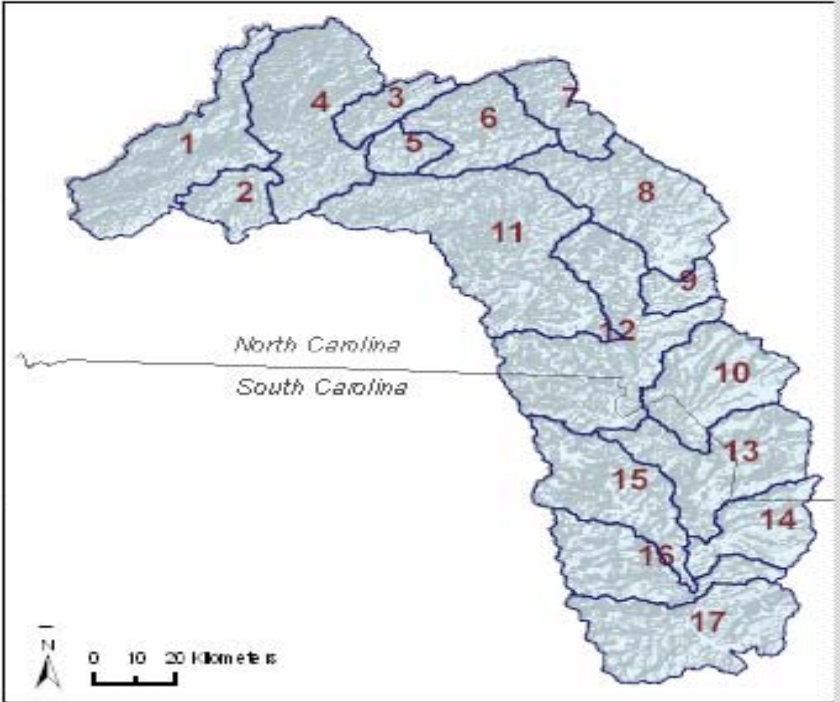
Subwatersheds

- 1 Lake James Seg 7
- 2 Old Catawba River
- 3 Lower Creek
- 4 Catawba R above Lk Rhodhiss
- 5 Lake Rhodhiss Seg 7
- 6 Lake Hickory Seg 7
- 7 Lookout Shoals Lake
- 8 Lake Norman Seg 4
- 9 Mt Island Lake Seg 14

User email address

\* An email notification will be sent to this address when your simulation is completed. It usually takes a day.

Catawba River Basin





# Hydroclimatology Decision Support

- Federal Energy Regulatory Commission dam relicensing
- Long-term water management



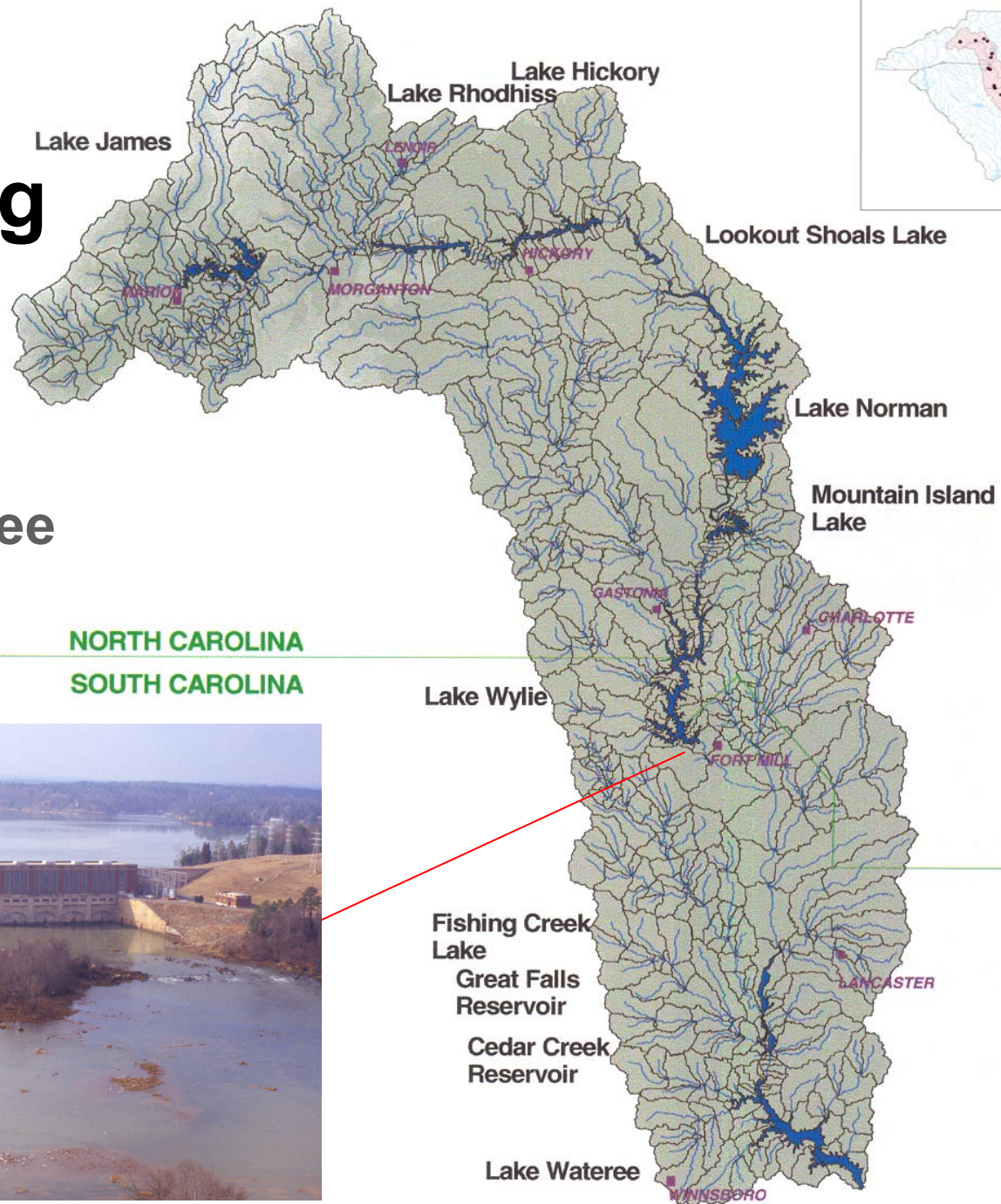
# Why Focus on Hydro Relicensing?

Our stakeholders agree that FERC relicensing is the most significant water resources activity

- All water resources stakeholders participate in some way
- 30/50-year license agreement with potential for flexibility or periodic adjustment
- First chance to integrate federal water and environmental laws
- Implications for interstate water agreements, economic development

# FERC Relicensing

## Duke Power and the Catawba/Wataeree River





# Agencies and Interests in the FERC Relicensing Process

## Federal Agencies



## Licensee

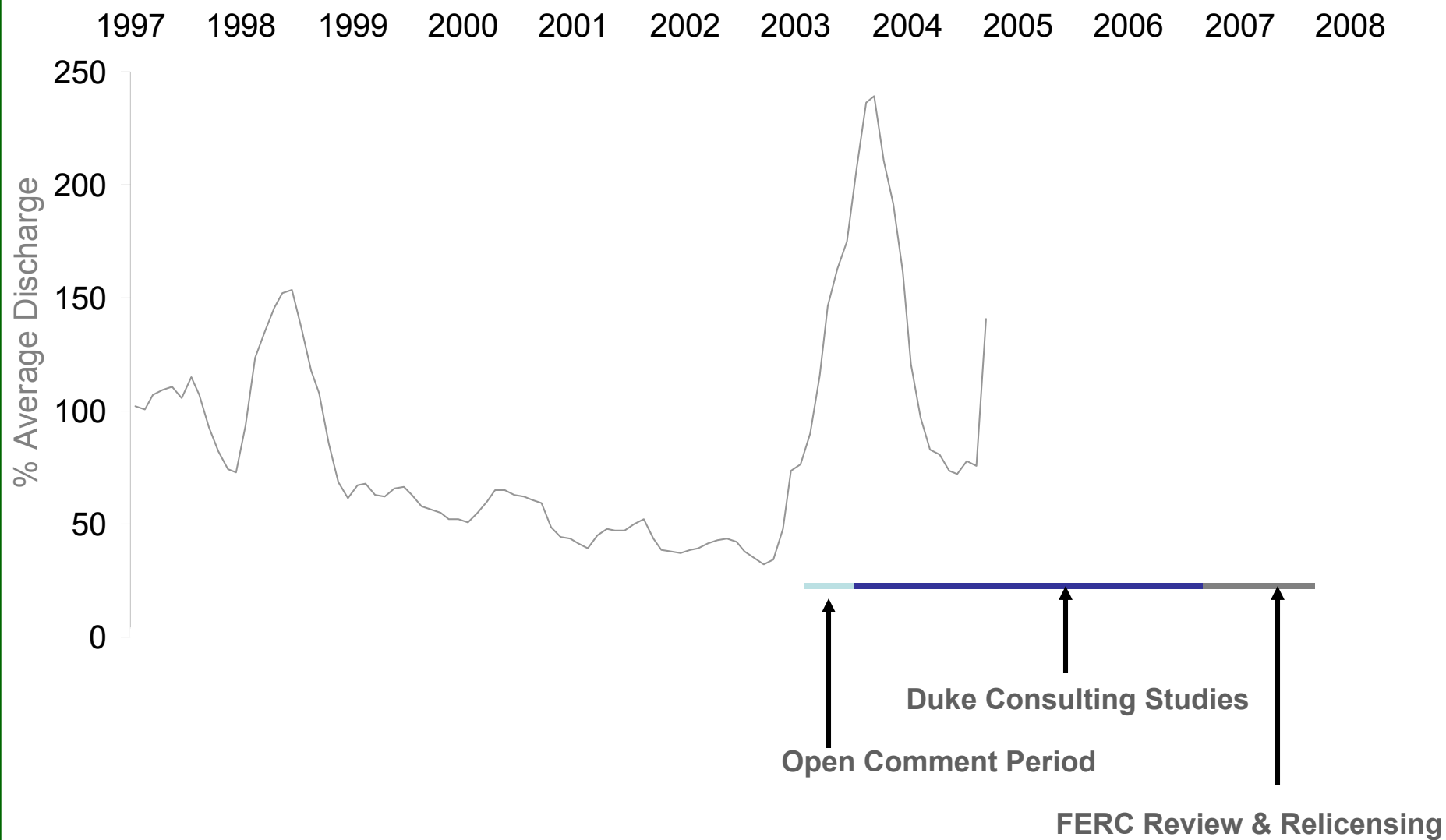


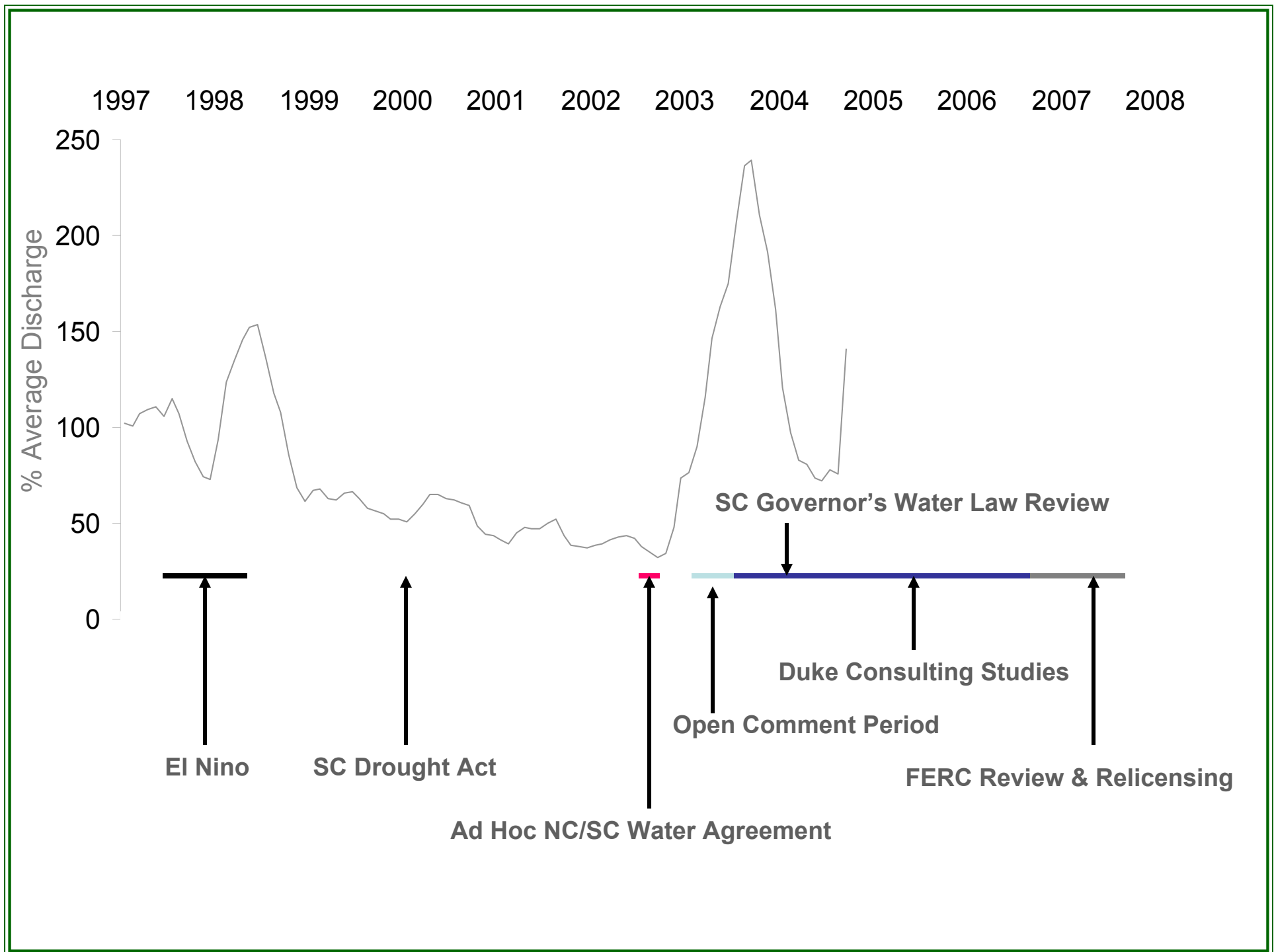
## Non-Agency Stakeholders



## State Agencies







# Study Groups

## Water Quality



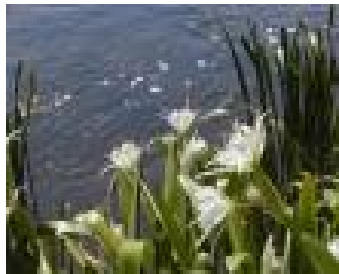
## Water Supply



## Recreation



## Fish and Wildlife and Habitat Enhancement and Protection

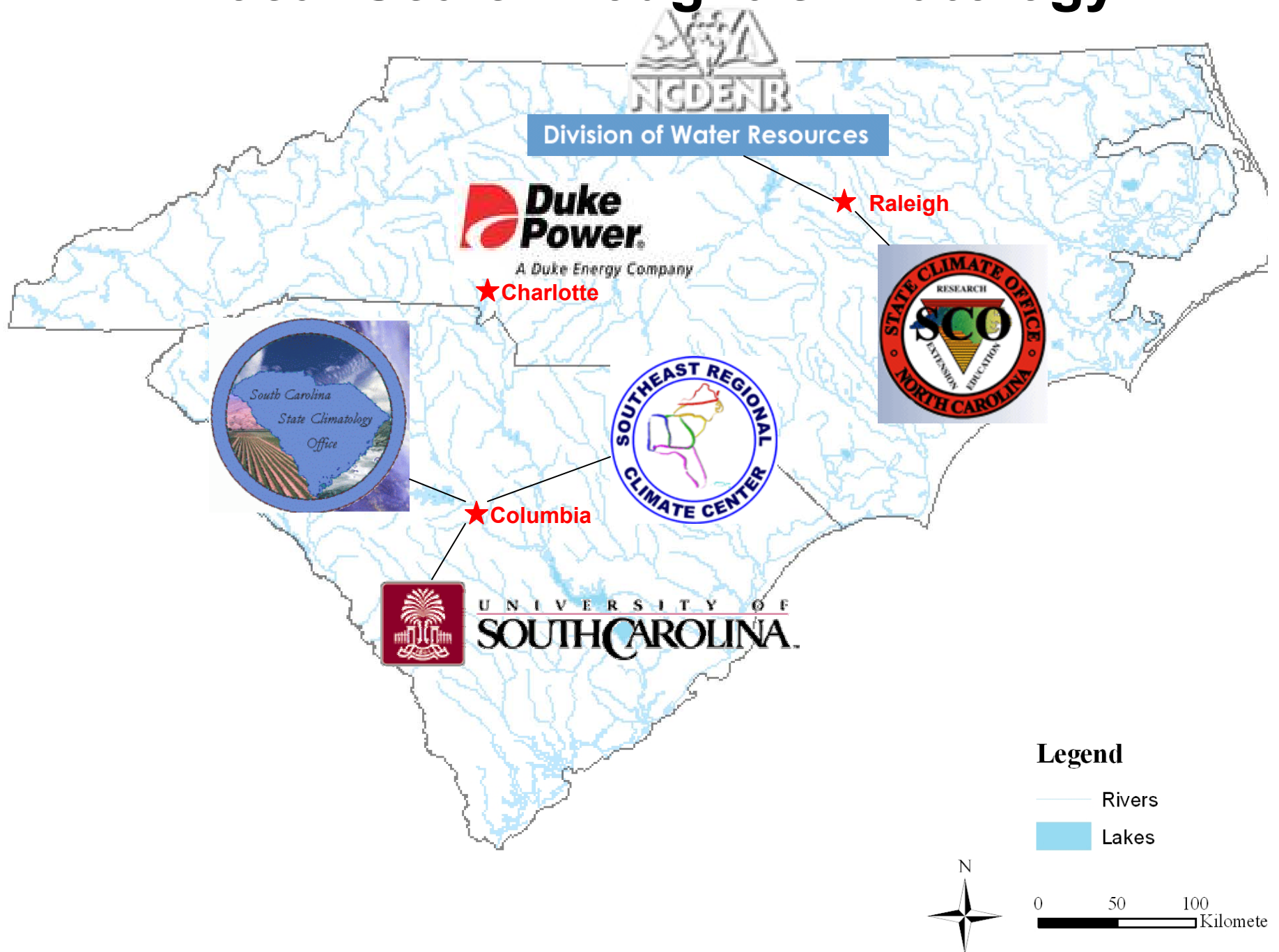


## Shoreline Management

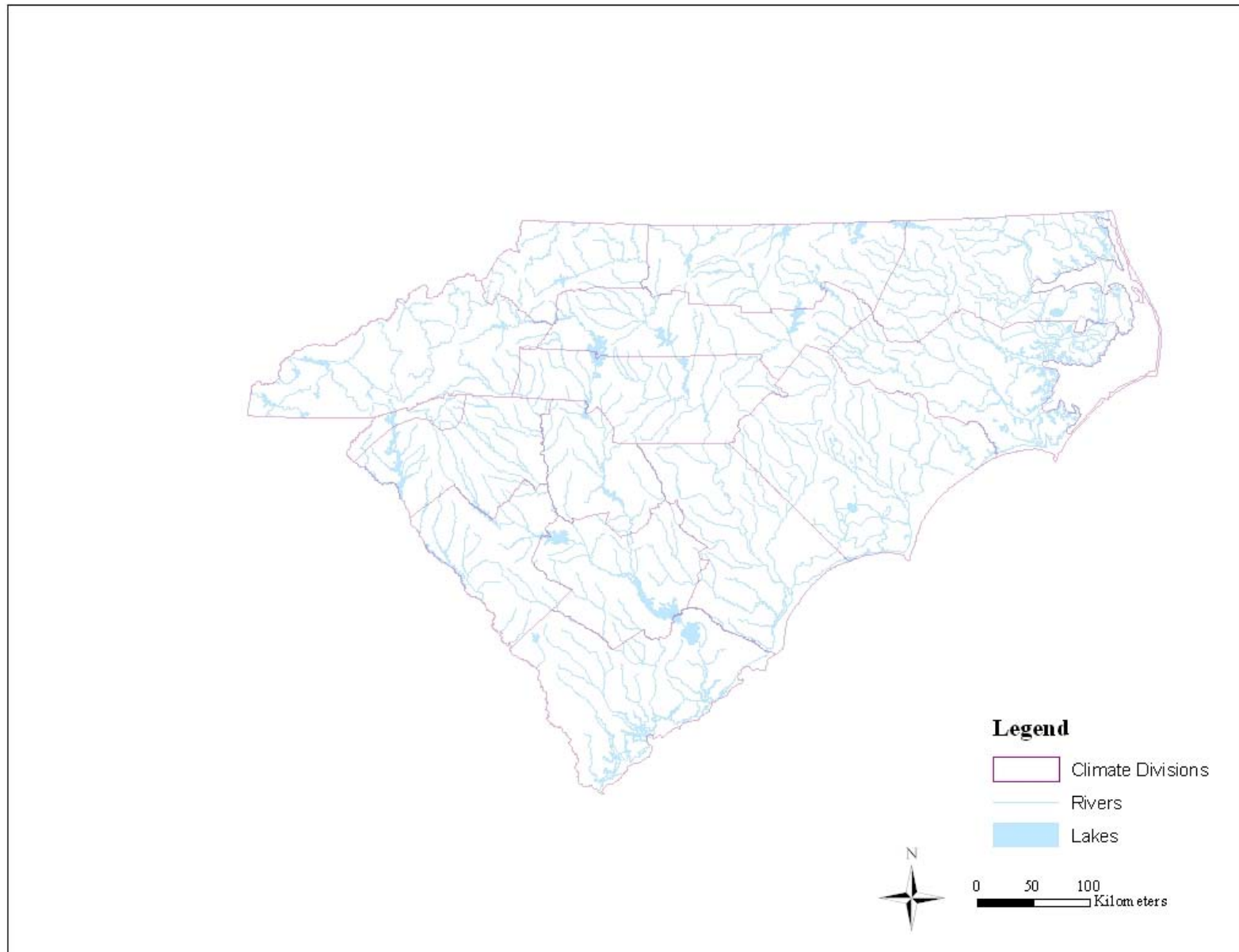




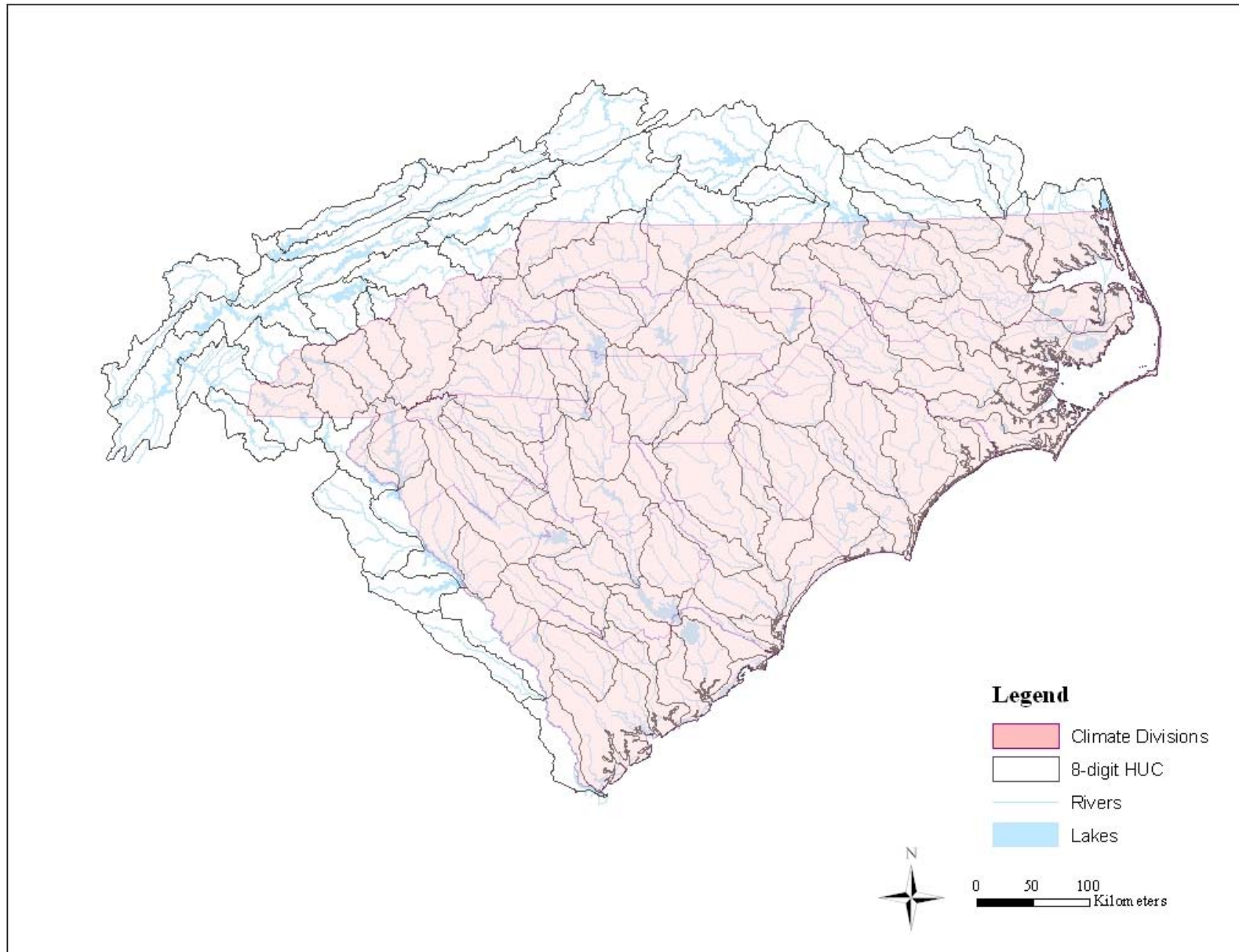
# A Local-Scale Drought Climatology



# Climatic Divisions



# 8-Digit Hydrologic Unit Codes



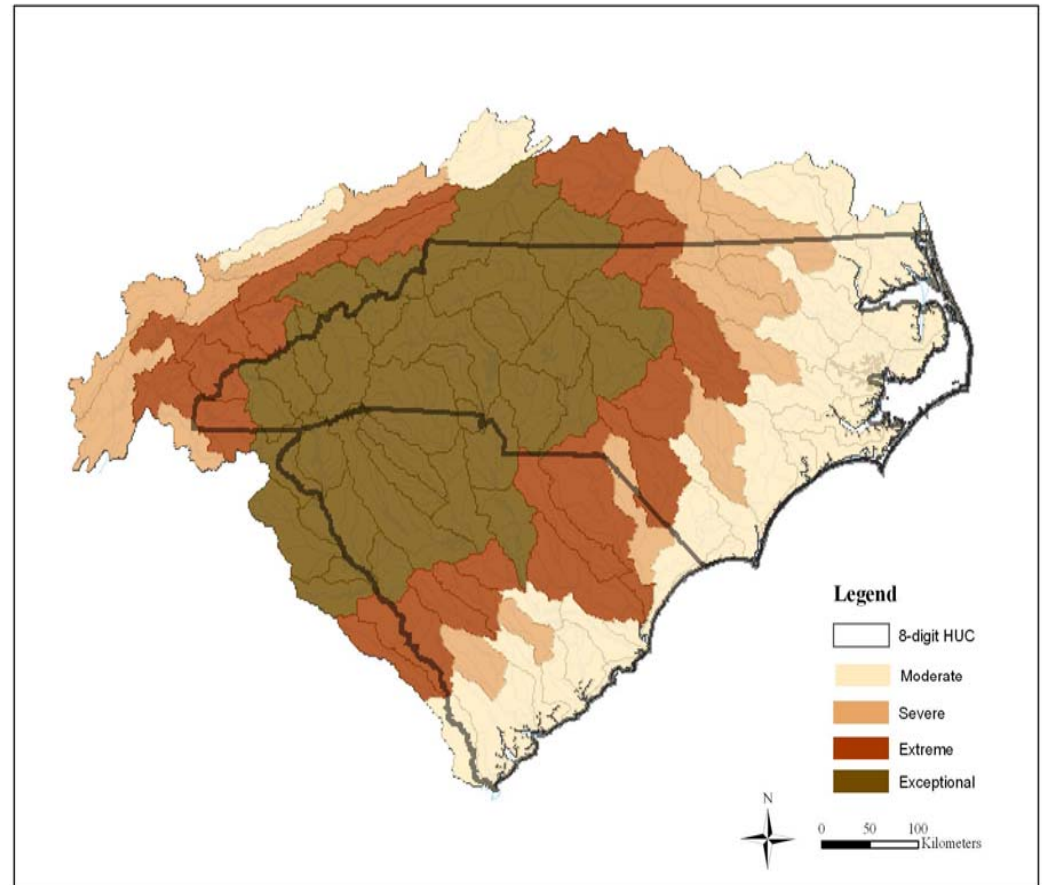
# Hydroclimatology Decision-Support Tool

Choose year and month:

Year	2005
Month	06

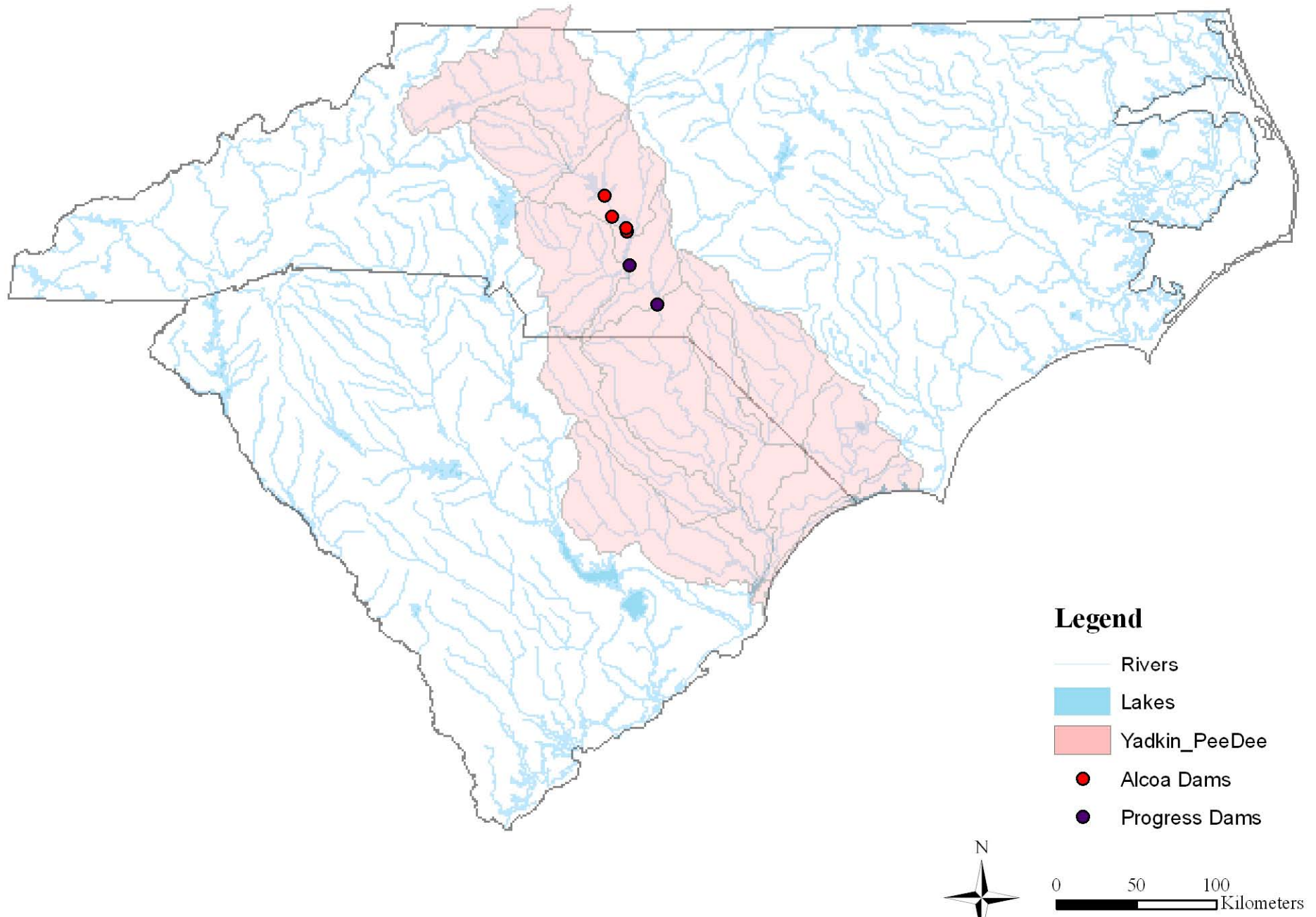
Choose weights for each drought index (must sum to 100%):

Stream flow Percentile	40%
PDSI	10%
PHDI	10%
3-month SPI	20%
6-month SPI	20%
12-month SPI	0%





# Yadkin – Pee Dee River Basin



# Downstream Consequences



NC Yadkin/Pee Dee Lakes:  
sample spring

# Downstream Consequences



NC Yadkin/Pee Dee Lakes:  
summer 2002



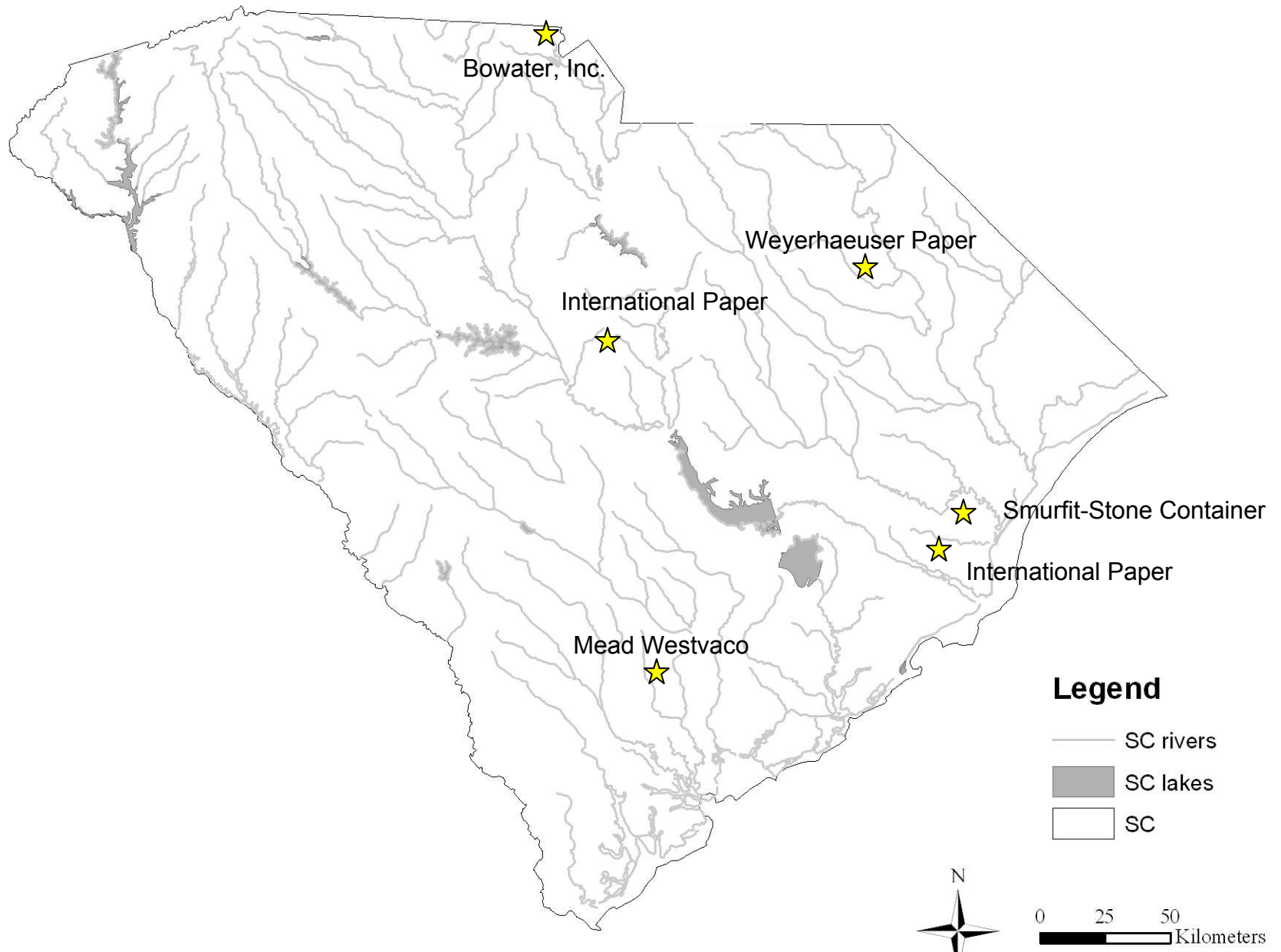
# Remaining storage during the 2002 summer crisis

RELEASE (CFS)	STORAGE DEPLETION TIME	JULY						
1500	93 DAYS	1	2	3	4	5	6	
1200	107 DAYS	7	8	9	10	11	12	13
900	133 DAYS	14	15	16	17	18	19	20
		21	22	23	24	25	26	27
		28	29	30	31			
		AUGUST						
			1	2	3			
		4	5	6	7	8	9	10
		11	12	13	14	15	16	17
		18	19	20	21	22	23	24
		25	26	27	28	29	30	31
		SEPTEMBER						
		1	2	3	4	5	6	7
		8	9	10	11	12	13	14
		15	16	17	18	19	20	21
		22	23	24	25	26	27	28
		29	30					
		OCTOBER						
			1	2	3	4	5	
		6	7	8	9	10	11	12
		13	14	15	16	17	18	19
		20	21	22	23	24	25	26
		27	28	29	30	31		
		NOVEMBER						
						1	2	
		3	4	5	6	7	8	9
		10	11	12	13	14	15	16
		17	18	19	20	21	22	23
		24	25	26	27	28	29	30

# Salt Water Intrusion



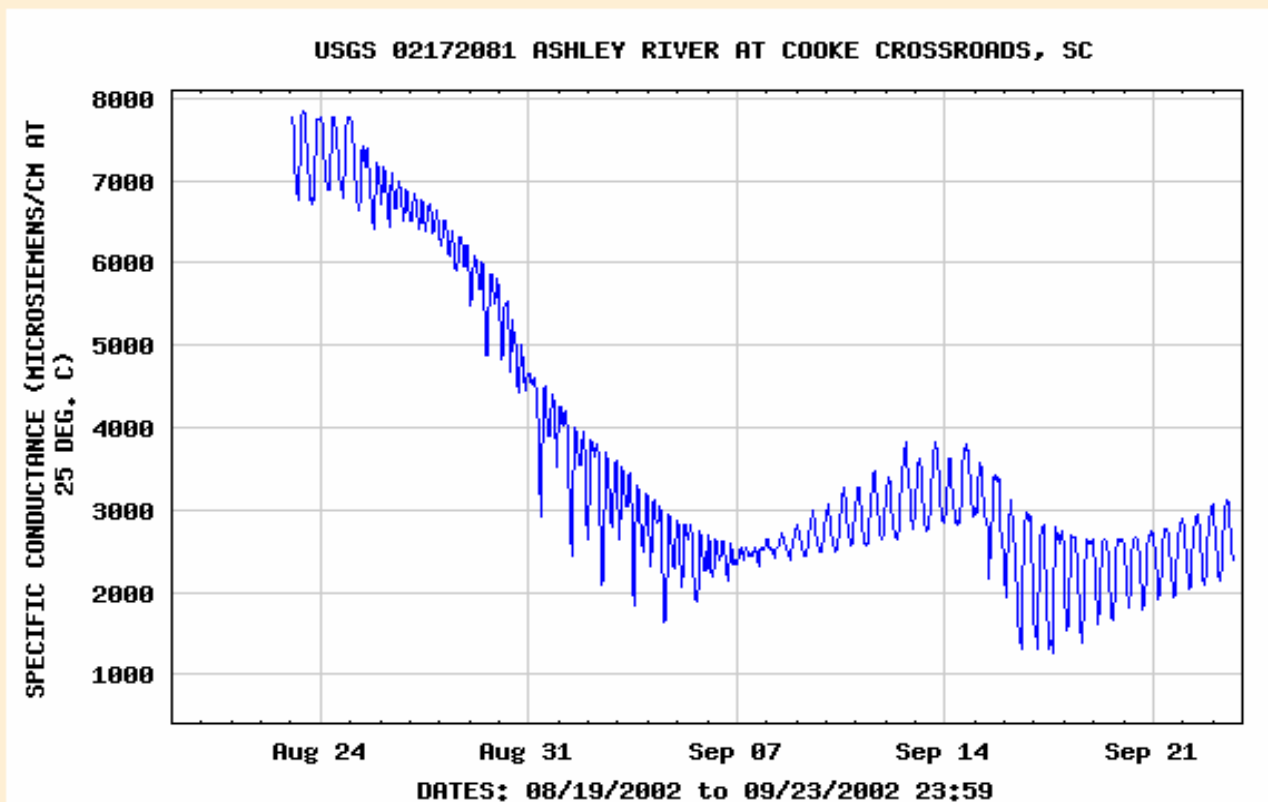
# SC Paper and Pulp Plants

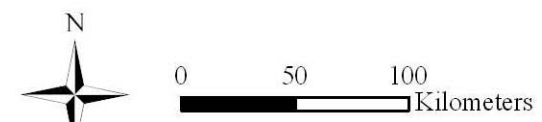
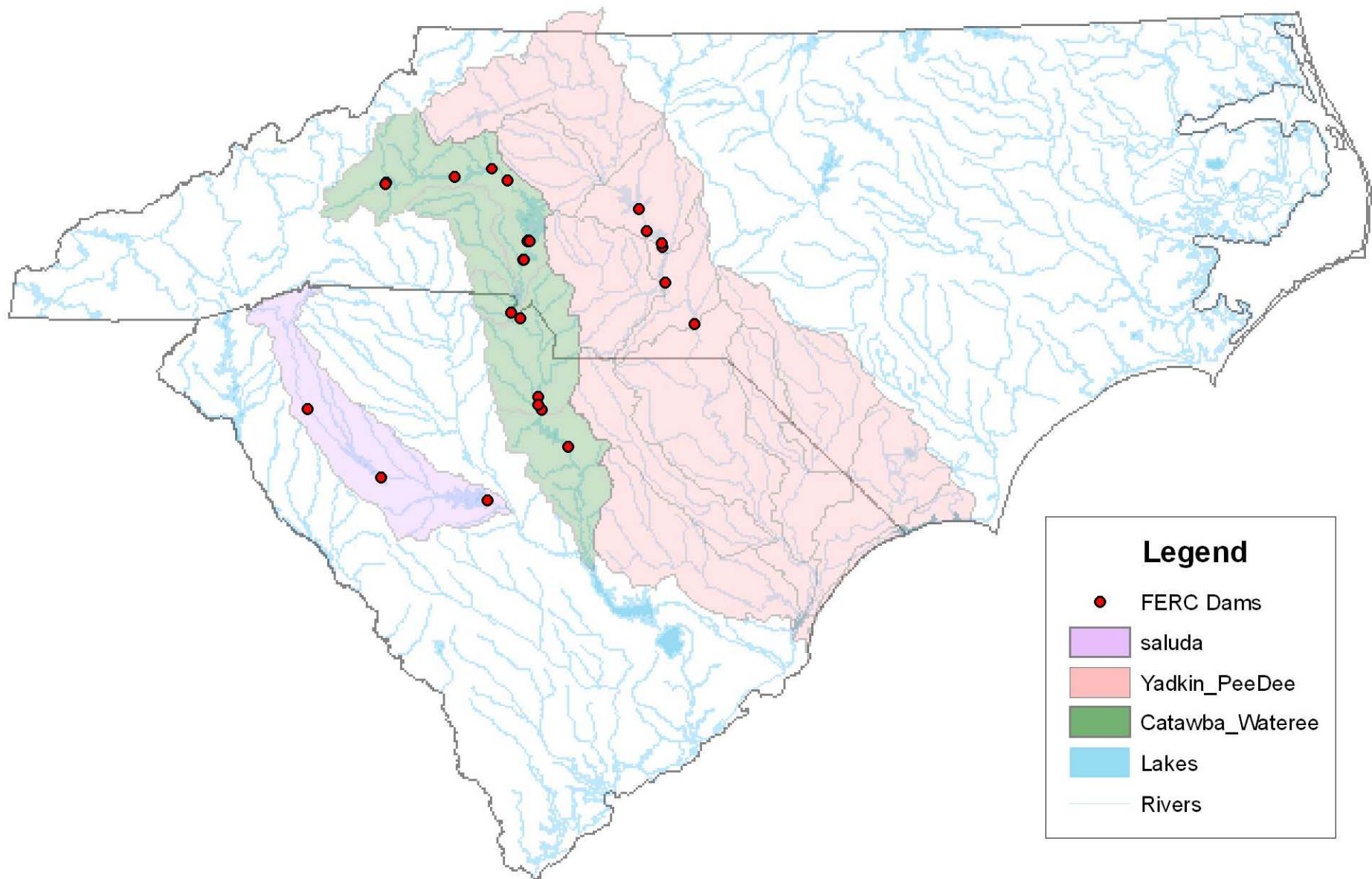


# Salt Water Intrusion Ashley River near Summerville

SPECIFIC CONDUCTANCE (MICROSIEMENS/CM AT 25 DEG. C)

Most recent value: 2,400 09-23-2002 16:00





# From Conversations to Partnerships

## CISA assessment period activities

- Entering and engaging in ongoing conversations
- Collaborating with stakeholders to address specific, salient issues (long-term implications, high risks)

## Future

- Continue and deepen engagement
- Expand research questions
- Develop and facilitate dissemination of products





Thanks to: Lauren Gregory,  
Jim Hussey, Kirsten Lackstrom,  
Jinyoung Rhee, Ohnika Singh

Sources: [www.cwrc.info](http://www.cwrc.info); <http://www.lakenormankeepers.com/>

